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15. SUPPLEMENTARY NOTES: The manual is prepared as an information document and users planning manual to support the Agency's 208 areawide waste treatment management and planning effort. It is a joint effort of the Office of Research and Development and the Office of Water Planning and Standards.

16. ABSTRACT: Pertinent to the implementation of State and areawide planning under Section 208 of P.L. 92-500, this manual provides an environmental management statement of procedures available for water quality management with particular emphasis on urban stormwater. The manual summarizes and presents in condensed form a range of available procedures and methodologies that are available for identifying and estimating pollutant load generation and transport from major sources within water quality management planning areas. Although an annotated chapter is provided for the assessment of non-urban pollutant loads, the major emphasis of the manual is directed toward the assessment of problems and selection of alternatives in urban areas, with particular concern for stormwater related problems. Also included in the manual are methodologies for assessing the present and future water quality impacts from major sources as well as summaries of available information and techniques for analysis and selection of structural and nonstructual control alternatives.

This manual is structured to present problem assessment and impact analysis approaches for several levels of planning sophistication. Simple procedures are recommended for initial analysis to develop the insight and problem understanding to guide the application of more complex techniques where required. Presented in three volumes the specific sections are as follows: procedures for assessment of urban and non-urban pollution sources and loadings, pollutional load stream impact analysis, methodology for evaluation and selection of control alternatives, rainfall runoff and water quality model applicability, land use and rainfall data analysis, runoff and water quality monitoring and parameter handbook, and cost and performance of structural and nonstructural pollution control alternatives.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Water quality, Assessments, Mathematical models, Systems analysis, Urban areas, Rural areas, Waste water--water pollution, Waste treatment, Rainfall, Runoff, Regional planning, Cost effectiveness--management methods	Areawide planning, Statistical analysis, Stream impact analysis, Treatment alternative evaluation, AAPM, Section 208, P.L. 92-500, Monitoring, Point source pollution, Nonpoint source pollution	13B

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AREAWIDE ASSESSMENT

PROCEDURES MANUAL

VOLUME III

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
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APPENDIX G

PART I

URBAN STORMWATER MANAGEMENT TECHNIQUES: PERFORMANCE AND COST

G.1 Introduction

G.1.1 Purpose of Appendix G and Its Relationship to Chapter 6

The Chapter 2 preliminary assessment presented a broad identification of major pollutant sources within an urban area, together with a perspective on the relative magnitude of pollutant loads generated in an urban setting by intermittant sources from combined sewer overflows and storm drainage systems. In Chapter 3, alternative technical approaches for the estimation of stormwater-related waste flow and quality were discussed. Various methods of analyses including steady-state and time-varying water quality modeling were presented in Chapter 5 to determine the impact of storm related pollutants on the quality of receiving waters. Chapter 6 presents a methodology for the evaluation of stormwater runoff control alternatives. The Manual user is guided through a worksheet approach to the development of a least cost mix of structural and nonstructural pollution control alternatives to meet previously identified water quality goals.

In support of Chapter 6, Appendixes G and H have been prepared. Appendix G provides the estimated performance capability and pollutant removal unit cost input to the alternatives methodology of Chapter 6 from the standpoint of nonstructural control of urban stormwater runoff. This is in contrast to Appendix H which presents performance and cost data for structural solutions to point source and nonpoint source pollution control. In order to make Appendix G responsive to the data input needs of the alternatives evaluation methodology of Chapter 6, the discussions of nonstructural management techniques have been formated into Land Management Control Alternatives and Collection Systems Control Alternatives.

G.1.2 Description of Appendix G, Parts I and II

Appendix G is presented in two parts. Part I has been specifically researched and written to be in concert with other portions of the AAPM. The approach taken in the development of nonstructural performance and cost data is at the same level of detail and sophistication as has been used elsewhere in the manual's development of the assessment methodology. For discussions and example presentation pertinent literature data are used in conjunction with assumed or site-specific constraints to arrive at reasonable estimates of costs and generalized effectiveness of stormwater management alternatives. When site-specific data are available in a planning area, they are to be used to provide a more accurate analysis for the decision matrix. Those site specific data which should be used include total annual precipitation, runoff coefficient, land-use patterns and population density, miles of street, miles of curb, sewer miles, number of combined sewer overflows, number and volume of combined sewer overflows per year, and the like. Although the performance and cost estimates developed in Part I are based on reliable literature sources, the estimates should not be mechanistically applied to specific planning areas without considering whether the expressed or implied assumptions are representative of existing conditions.

Part II of this appendix consists of EPA Report No. 600/2-77-083, "Storm Water Management Model: Level I-Comparative Evaluation of Storage-Treatment and other Management Practices." The report describes simplified procedures for obtaining a preliminary estimate of the magnitude of stormwater discharges and the associated costs of control. The approach is similar to that used in Part I in that it is designed as a "desktop" procedure to compare selected alternative control technologies. It has been included in its entirety as Part II in order to provide an alternate approach to the evaluation of stormwater management practices. Unlike Part I which discusses a great number of individually-treated control techniques, Part II discusses only street sweeping, sewer flushing, catch/basin cleaning, and storage-treatment. However, it does present a graphical method for combining processes in series or parallel, arriving at a least-cost optimal combination of storage-treatment and other management practices using marginal cost analysis.

Part I of this appendix considers (1) Sources and Gross Pollution Loads of Urban Runoff, (2) Land Management Control Alternatives, and (3) Collection Systems Control Alternatives. The gross pollution loading relationships given in Chapter 3 are compared with quantitative measurements of individual sources such as street pollution and the buildup of municipal wastewater solids in combined sewers. The determination of the pollutional load establishes the baseline from which the performance capability and effectiveness of specific management techniques are calculated. The cost of various control measures are then estimated based on available literature references.

As previously mentioned, the techniques discussed in Part I are classified into two categories. The first category is Section G.3, Land Management Control Alternatives. The measures discussed are street cleaning, erosion control, storage in residential ponds, porous pavement, chemical use control, and air pollution control. The second category is Section G.4, Collection Systems Control Alternatives. The measures discussed are storage in existing sewer system, reduction or elimination of excessive infiltration and inflow, periodic sewer flushing and scraping, and catch basin cleaning.

Two additional management techniques, considered to be structural or semi-structural control methods, are also discussed in the second category. The first is sewer separations for which the conclusion is drawn that due to cost considerations this technique is feasible only in a developing area. The second semistructural control technique entails the installation of swirl concentrators at combined sewer overflow points. The discussion in this appendix considers swirl devices as flow regulators in combined sewer systems which will maximize in-line storage while providing a BOD removal capability not found in other flow regulating devices. On the other hand, the discussion of swirl devices in Chapter 6, covered in 6.4.2.7, Storage/ Treatment Methodology, considers these overflow regulators (which <u>may</u> be designed for solids removal) antecedent to off-line stormwater storage/ treatment systems.

For each stormwater management practice discussed, the same general approach is followed. A brief review of previous studies is given to describe the range of potential applicability and to point out the agreement or disparity of the literature data and results. The potential applicability, performance

capability and costs are presented in example format. In those instances were assumptions are made; for example, population density, land use activities in relation to street miles or sewer miles, precipitation and runoff coefficients; they are for illustrative use in the example. (For individual planning areas, site specific data are to be used where available, or a reasonable estimate in lieu thereof.) The costs which are given, therefore, are reflective of the example assumptions made and must be viewed in that light. Site-specific data applied to the example problem might substantially change the load reduction potential and cost projections in any individual planning area.

It is important to note that basic assumptions made or data used in Parts I and II are not identical and therefore the costs developed through a Part I approach may not be exactly comparable to the costs resulting from a Part II approach. For example, the cost of street sweeping given in Part I is $10.40 per curb-mile including disposal of sweepings versus $7.00 per curb-mile as given in Part II. The latter unit cost does not include disposal of the sweepings, nor does the optimization analysis provide for its inclusion.

From the standpoint of the context in which Parts I and II have been prepared and their relationship to the Chapter 6 methodology, the following comment may be obvious to users of the Manual but it bears additional attention. The Part I discussions of management alternatives have been prepared to furnish performance and cost inputs to Chapter 6. It is then the function of Chapter 6 to use the stormwater management practices performance and cost alternatives data from Appendix G, Part I, and the structural systems performance and cost alternatives data from Appendix H, to arrive at an optimal mix of structural and nonstructural pollution reduction alternatives which satisfy the previously developed load-reduction imperatives.

Conversely, Part II is a self-contained nonstructural/semi-structural alternatives evaluation methodology which provides a least-cost solution based on a limited number of technical alternatives, and which does not optimize among structural and nonstructural techniques. Again, it is being included in this appendix to demonstrate that more than one evaluation approach is available.

G.1.3 Literature Sources and Data Reliability

The text which follows is designed to fill a need for specific and illustrative information on management alternatives to input a first-level decision matrix. The process performance and cost data are not intended to be a complete listing or compilation of all the available literature concerning the sources, loadings, and alternative management practices for the control of urban nonpoint source pollution. There are other assessment and state-of-the-art documents available for an overview, and many of these have been used as a reference source for the material presented in this appendix.

The first level source of information is the library of EPA reports generated by the grant and contract activities of the Storm and Combined Sewer Section, Municipal Environmental Research Laboratory, Cincinnati. As a result of these and other EPA Research and Development projects, much information has been generated in defining problems and in the application of management techniques to the abatement of urban stormwater pollution. From some reports, information has been extracted directly. However, other reports were useful for their bibliographies which referred to original studies. In this case the original source of data could be examined and analyzed more critically for specific inclusion herein.

For much of the work presented in this appendix, data from the original, recent, and not so recent studies were used. As input to the development of the sources and gross pollution loads of urban stormwater runoff, data from those studies were analyzed and, in the oft occurring instances of irreconcilable data due to differences in experimental design or unrealistic experimental conditions, those data most closely approximating real-world experience were used. As a result of the evaluation of background data, the AAPM user can utilize the analytical results and cost performance estimates with confidence in a first-level planning exercise.

At this point, it should be restated, as it was stated originally in Chapter 6, that from the universe of research, demonstration, and on-site studies which have been carried out for the assessment of nonstructural technology for control of urban stormwater runoff pollution, a welter of data for performance capabilities and costs is available. Since the

information presented in this appendix has been collected from available literature and because it will be used in a preliminary way for the evaluation of alternative pollution control options with respect to performance and costs, it has been necessary to establish a quality measurement to relate the data from all sources.

The concept of "relative reliability" represents a reasonable indication to the user of this information regarding the nature and extent of the experience/data base upon which the cost or performance information is based. Although the judgement of the relative reliability of the information is subjective, it establishes for the user a relative confidence level for his alternative evaluation, indicating in the appropriate area of the alternative spectrum where data are deficient or where data are sufficient for reasonable confidence in definitive decision making. Using the relative reliability of the data, the user is directed away from making a major decision among a number of potentially usable techniques based on insufficient or unreliable information.

The relative reliability concept is stressed in order to convey to the user community that the information presented here, upon which decisions are based, results from studies conducted with differing levels of sophistication. Although the best available information has been used, further research and experience in nonstructural management techniques will result in establishing a greater confidence in the precision and accuracy of currently available data and a greater confidence in the application of the data in a decision-making process.

G.2 Sources of Gross Urban Runoff Pollutant Loads

G.2.1 Sources

Water pollutants from urban areas resulting from rainfall originate from a number of sources. For example, separate storm sewer pollution is generally recognized as pollution washed off the urban area by rainfall. Combined sewers used for both stormwater and municipal sewage have an additional pollutional component due to solids accumulation and escaping wastewater. During dry weather periods municipal sewage solids settle out in the sewer and are flushed into the receiving stream by the next rainfall of sufficient

intensity to cause resuspension and overflows. Also, since a portion of the combined sewage overflows upstream of the treatment plant during wet weather, a portion of the municipal sewage generated by the population of the urban area during a storm event goes directly to the receiving stream.

Stormwater loads may be reduced by employing various combinations of structural end-of-pipe control techniques and urban runoff management practices. The objective of Part I of this appendix is to examine the potential effectiveness and costs of the more prominent management practices available. Structural alternatives; such as deliberate interception, storage and treatment; will not be considered except for purposes of comparison. These are analyzed in detail in Chapter 6 and in Part II of this appendix.

G.2.2 Determination of Source Loads

In order to assess the effectiveness and costs of each of the various urban stormwater management practices the relative magnitude of pollutant loads from combined sewer overflows and from separate stormwater runoff must be estimated. Each of these loads is affected differently by the application of the various management options. For example, street sweeping can reduce the amount of urban dust-and-dirt which will be washed off the urban area into the receiving stream during wet weather. Similarly, periodic combined sewer flushing can reduce the amount of settled solids which are washed into the receiving streem during rain storms.

A relationship between combined sewer and separate sewer BOD pollutant loadings which is often used is that of Heaney et al. (1). Using actual sewer effluent measurements from seven urban areas it was reported that for equivalent area and precipitation, combined sewer BOD loadings averaged 4.12 times higher than separate sewer loadings. An independent survey of available data conducted by Lager and Smith (2) found that average BOD concentrations in combined sewage are 3.83 times those found in separate sewers (115 mg/1 vs. 30 mg/1).

Rather than merely employing these average values (which are calculated independent of community size), it is necessary for the purpose of this appendix to attempt to confirm these ratios through a quantitative analysis of measurements of individual sources of urban stormwater pollutants, such

as street pollutants and the accumulation of municipal wastewater solids in sewers, and to compare these values with the gross loading relationships developed in Chapter 3.

G.2.2.1 Separate Stormwater Loads

Many attempts have been made to relate stormwater loads to land use. One general procedure for predicting runoff quality that was outlined in Chapter 3 is based upon research done by the University of Florida for the Environmental Protection Agency. This procedure, which relates runoff quality to land use and population density, estimates loads via the following relationships:

$$M_s = \alpha(i,j) \cdot R \cdot p_1 (PD_d) \cdot \gamma \qquad \text{(G-1)}$$

$$M_c = \beta(i,j) \cdot R \cdot p_1 (PD_d) \cdot \gamma \qquad \text{(G-2)}$$

where:

M_s = pound of pollutant (j) from land use (i) with separate and unsewered conveyance (lbs/acre-yr)

M_c = pound of pollutant (j) from land use (i) with combined sewer conveyance (lbs/acre-yr)

$\alpha(i,j)$ = constant for pollutant (j) and land use (i) with separate and unsewered conveyance (lbs/acre-in)

$\beta(i,j)$ = constant for pollutant (j) and land use (i) with combined sewer conveyance (lbs/acre-in)

R = annual precipitation (in/yr)

$p_1 (PD_d)$ = population function

PD_d = population density (persons/acre)

γ = street sweeping effectiveness factor

Applying these relationships to a hypothetical urban area possessing the average developed land use characteristics of 248 urbanized areas in the United States (58.4% residential, 8.6% commercial, 14.8% industrial, and 18.2% other developed) Heaney et al. developed the following expression for the average annual BOD load from separate storm sewers as a function of population density (1):

$$\bar{M}_s = 0.467 \cdot R \cdot (0.142 + 0.218PD^{0.54}) + 0.457R \quad \text{(G-3)}$$

where:

$\bar{M}_s$ = average annual BOD loading from separate storm sewers (lb BOD/acre-yr)

R = annual precipitation (in/yr)

PD = population density of urbanized drainage area (persons/acre)

It is important to emphasize that similar relationships may be developed for other pollutant parameters of interest, e.g., suspended solids or nutrients. Most evaluations of urban management practices, however, have been conducted with BOD removal as the primary concern. For example purposes the estimations and analyses in this appendix will also be developed on a BOD basis.

The average annual precipitation for the seven cities from which runoff data was used to develop Equation (G-3) was 36 inches/year. Therefore, substituting this value for R, Equation (G-3) becomes:

$$\bar{M}_s = 18.8 + 3.67\ PD^{0.54} \quad \text{(G-4)}$$

Population density, in turn, is known to increase with community size in a fairly regular way, as described by the following relationship derived by Smith (3):

$$PD = 0.3\ POP^{0.304} \quad \text{(G-5)}$$

where:

POP = community population

Equation (G-5) is then substituted into Equation (G-4) to obtain the following relationship for estimating BOD loading from separate storm sewers as a function of community population.

$$M = 18.8 + 1.9\ POP^{0.1642} \quad \text{(G-6)}$$

This relationship is shown in Figure G-1 (curve A). It can be seen that separate sewer BOD loading (lb BOD/acre-year) is relatively insensitive to community size, ranging from about 25-35 lb BOD/acre-year.

The validity of this loading relationship may be tested using published values of BOD accumulation upon urban surfaces. A portion of the pollutional

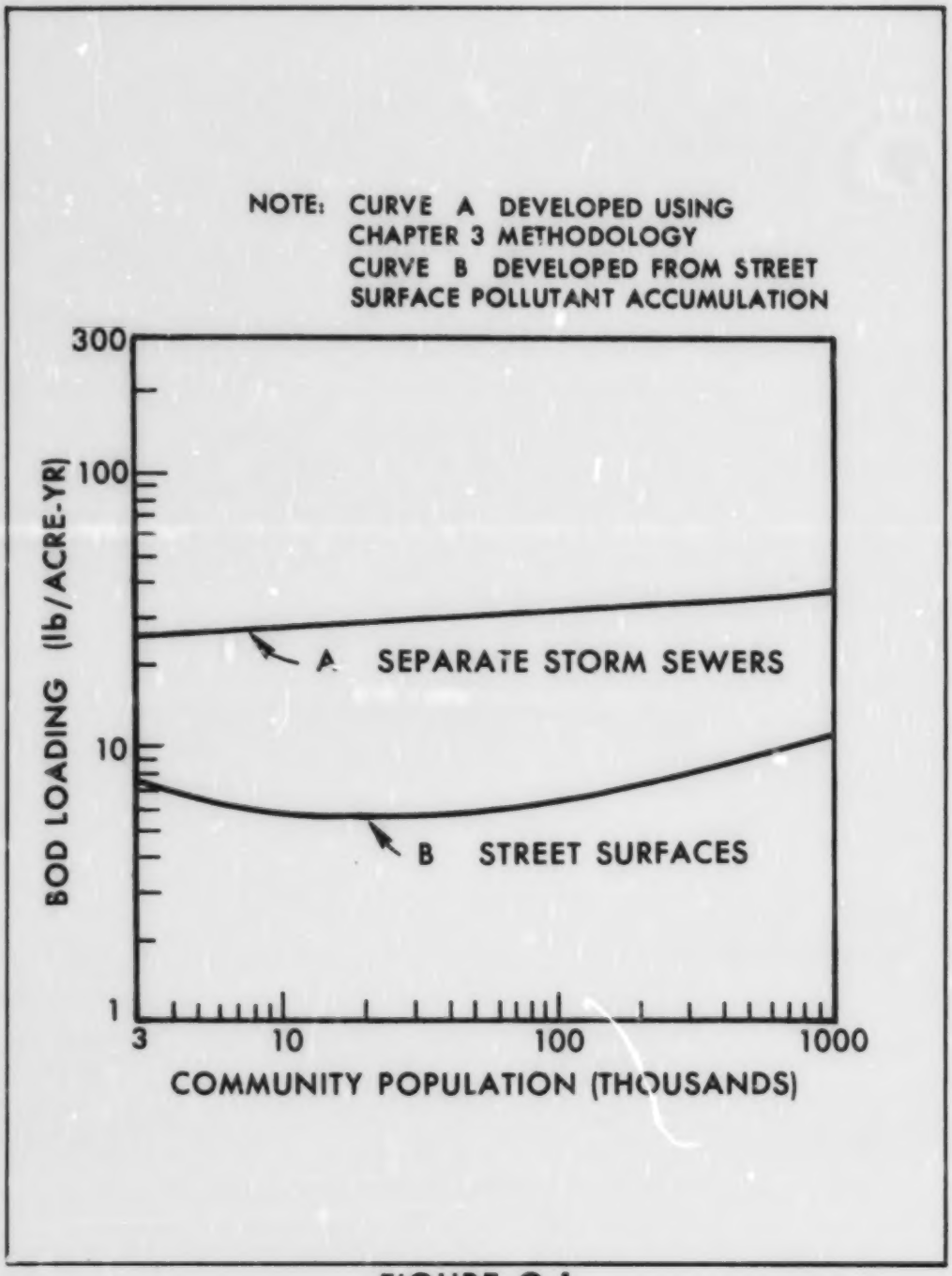

FIGURE G-1
ESTIMATED BOD LOADING IN URBAN RUNOFF
AS A FUNCTION OF COMMUNITY SIZE

load attributed to separate storm sewers is contributed by the dust-and-dirt which accumulates on the streets of the urban area. This load can then be reduced by means of street sweeping. During the summer of 1967, the American Public Works Association (4) conducted street sweeping measurements over a four-week period in the City of Chicago. The results of the study showed that the amount of litter which accumulates on the streets ranged from 26-422 lb/day/mile of curb. The dust-and-dirt fraction of the litter was defined as that fraction passing a screen with 1/8-inch openings. The amount of dust-and-dirt accumulated was measured as 21-275 lb/day/mile of curb. It was found that most of the BOD in street litter was contained in the dust-and-dirt fraction. The dust-and-dirt fraction was pulverized in a blender and dissolved in water. Without filtering, the BOD and COD of the water and dust-and-dirt mixture was found using standard techniques. The concentration of BOD in the dust-and-dirt fraction ranged from 3-7.7 mg/g. The amount of BOD accumulated varied with the type of land use and tended to be greater in high density residential areas. The weighted estimate for BOD accumulation on the streets of Chicago was 0.4 lb BOD/day/mile of curb or 0.8 lb BOD/day/mile of street. An interesting and, perhaps, significant result of the study was that the amount of BOD collected from the street was not related to the time since the last rainfall.

Using U.S. Department of Transportation data provided in the APWA report (4), miles of streets can be related to community size. This relationship is plotted as curve A in Figure G-2. Combining this with Equation (G-5) yields a relationship between community size and miles of streets/acre (curve B in Figure G-2), which when further multiplied by the APWA BOD accumulation rate for streets (0.8 lb BOD/day/mile x 365 days/year = 292 lb BOD/year/mile of street) yields curve B in Figure G-1. This provides a relationship for the potential annual BOD available from street surfaces as a function of community size.

Further examination of Figure G-1 reveals that the BOD loading values derived from the street sweeping experiments (curve B) are about one-fourth the loading when estimated from the BOD concentration found in separate storm sewers (curve A). A possible explanation for this factor difference is that the lower values of curve A are based upon dirt-and-dust available from street

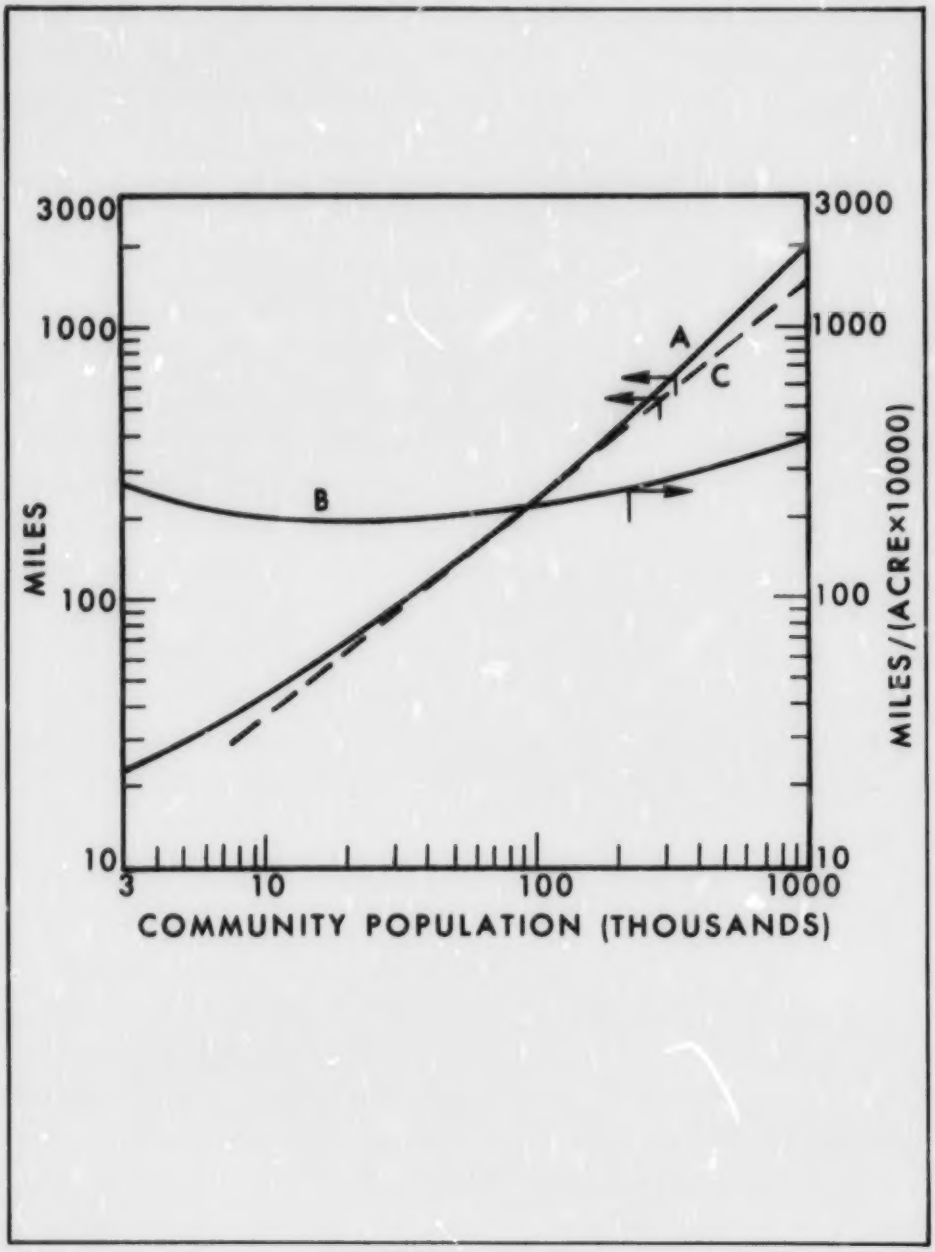

FIGURE G-2
RELATIONSHIP BETWEEN COMMUNITY SIZE AND (A) TOTAL MILES OF STREET; (B) STREET (SEWER) MILES PER 10,000 ACRES; AND (C) TOTAL MILES OF SEWER

surfaces only. These materials, however, accumulate at varying rates on all urban surfaces, including roof tops, parking lots, sidewalks, and pervious areas and are available to be washed from all these surfaces into separate storm sewers during rainfall events. This fact is reinforced by recalling that one of the conclusions of the Chicago study was that the amount of dust-and-dirt swept from the streets seemed to be independent of the time since the previous rainfall, probably due to the fact that rainfall tended to wash dust-and-dirt from the non-street areas onto the street.

As a rough approximation it might be assumed that the dust-and-dirt cover is, on the average, the same for all urbanized surfaces. In a careful study of urban land use for 53 central cities and 33 satellite cities Bartholomew (5) found that roughly 56% of the land was urbanized and that streets occupied an average of 28.1% of the urbanized area. Thus, it can be seen that the ratio of street BOD loading as recorded by APWA (Figure G-1, curve A) to the gross loading from the total urbanized area as estimated by Chapter 3 procedures (Figure G-1, curve B) is roughly the same as the ratio of street area to total urbanized area measured by Bartholomew, i.e., 25% vs. 28.1%. This tends to lend credence to both sets of estimates. More importantly, it leads to the further conclusion that the amount of BOD (in the form of dust-and-dirt) which can be removed from the streets (using current street sweeping practices) is not likely to exceed the amount actually on the street surfaces which accounts for only about 25% of the total loading.

G.2.2.2 Combined Sewer Loads

The experiments on buildup of sanitary sewage solids in a pilot sewer conducted by FMC Corporation (6) can be used in an attempt to account for the additional loading observed from combined sewers. In this work, FMC allowed raw sanitary sewage to flow through 12-inch diameter and 18-inch diameter pilot sewers both 790 feet long. The amount of solids accumulation was measures in terms of TOC (total organic carbon) as a function of time and distance along the sewer. As might be expected, the measurements were scattered but by averaging the accumulation per length of sewer per unit of time over the first 267 feet and over the entire length for the times used (1.75, 3.92, and 7.83 days) the average rate of accumulation was 2.09 lb TOC/mile/day. It was also found that the BOD of the accumulated solids

equaled about 1.8 times the TOC measurement. The suspended solids concentration of the raw sewage used by FMC was 133 mg/l which is low compared to a more normal value of 200 mg/l. If the measured accumulation is multiplied by the ratio 200/133 the value for normal sanitary sewage is 5.66 lb BOD/mile/day or 2067 lb BOD/mile/yr.

Thus, if the length of sewer can be stimated, the loading due to accumulation of sanitary sewage solids can also be estimated. One relationship developed by Smith (3) is shown below:

$$\text{Feet of installed sewer/capita} = 54\ (PD)^{-0.65} \qquad \text{(G-7)}$$

Combining this expression with Equation (G-5) the following relationship for miles of sewer versus community size results:

$$\text{Miles of sewer} = 0.02237\ POP^{0.8024} \qquad \text{(G-8)}$$

This relationship is shown plotted by the dashed line in Figure G-2 (curve C). It can be seen that the miles of sewer is very similar to the miles of street. The relationship for miles of street is probably more reliable as an estimate of length of sewer. If one assumes that the miles of sewer is equal to the miles of street, the expression for miles of sewer per acre as a function of community size becomes the same as curve B in Figure G-2. Multiplying miles of sewer/acre times 2067 lb BOD/mile/yr. gives the loading in terms of lb BOD/acre-yr. caused by flushing of settled sanitary sewage solids from combined sewers during the wet weather. This relationship is plotted as a function of community size in Figure G-3 (curve A).

Some raw sanitary sewage will also escape into the receiving stream during overflow periods and contribute to the difference between separate storm sewer and combined sewer loadings. Assuming that the production of sanitary sewage can be estimated as 0.17 lb BOD per capita per day, the equivalent loading is 62.05 (365 x 0.17) times the population density in persons/acre. Combining this relationship with Equation (G-5) gives the following equation for loading due to raw sewage escape:

$$\text{lb BOD/acre-yr.} = 18.62\ POP^{0.304} \qquad \text{(G-9)}$$

A survey of combined sewer problems conducted by APWA (7) in 1967 showed that because of wet weather, treatment plants (197 plants surveyed) bypass an

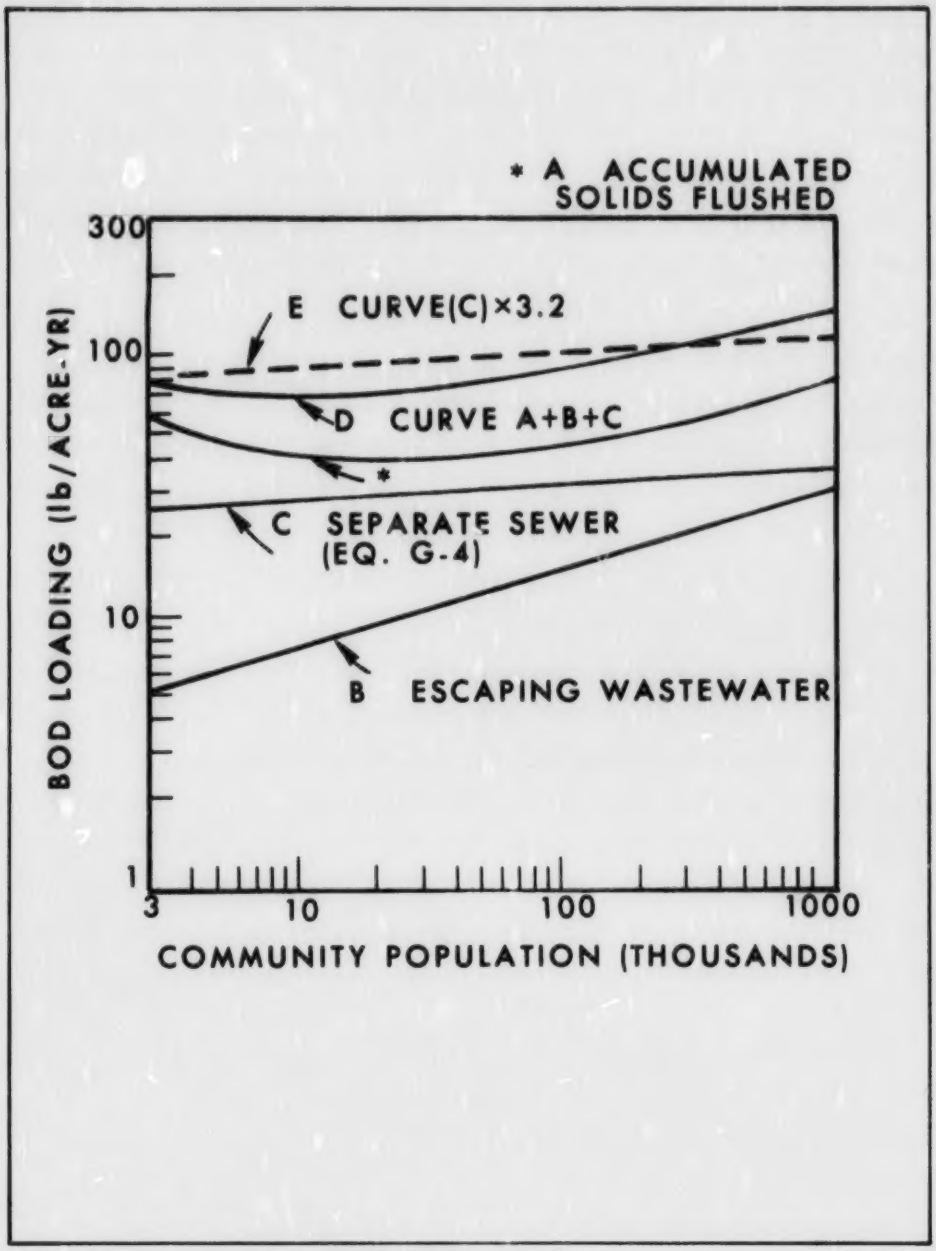

FIGURE G-3
ESTIMATED BOD LOADINGS
AS A FUNCTION OF COMMUNITY SIZE FOR:
(A) ACCUMULATED SOLIDS FLUSHED FROM SANITARY SEWERS; (B) ESCAPING WASTEWATER; AND (C) SEPARATE SEWERS.

average of 350 hr/yr or about 4% of the time. The fraction of raw municipal sewage which escapes during bypassing can be shown (8) to depend on the ratio of treatment plant capacity (MGD) to actual dry weather flow (MGD). The fraction escaping ranges from 48% when the ratio is ten, to 67% when the ratio is one. If a nominal value of 60% corresponding to a ratio of three is used, the loading caused by bypassed municipal sewage during wet weather can be estimated as 2.4% of that given by Equation (G-9), which is plotted as a function of community size in Figure G-3 (curve B).

Adding these two sources of BOD gives an incremental loading difference between storm and combined sewer discharges of 57 to 180 lb BOD/acre-yr. If this increment is now added to that estimated for pollution for from separate storm sewers using Equations (G-4), the overall estimate for combined sewer loading may be found. This is accomplished graphically in Figure G-3 by adding curves A, B, and C to derive curve D, the combined sewer loading relationship.

The seven measurements used for deriving the factor 4.12 are shown in Figure G-4. The dashed line (curve C) represents a factor of 4.12 times curve A. It can be seen that all but one of the measurements fall below the line. If the ratio of the loading for each point is divided by the equivalent estimate for separate storm sewers from curve A the average ratio becomes 3.2 instead of 4.12. The ratio of the loading for each point is divided by the equivalent estimate for separate storm sewers from curve A the average ratio becomes 3.2 instead of 4.12. The ratio of 3.2 is shown as curve B in Figure G-4. Using a factor of 3.2 instead of 4.12, the estimated loading relationship for combined sewers has been calculated and is shown as curve E in Figure G-3. Comparing curves D and E, it is seen that the two estimates agree well if the factor of 3.2 between loading of separate storm sewers and combined sewers is used. Table G-1 summarizes the calculations employed in defining the curve relationships in Figures G-1, G-2, and G-3.

From the analysis above, the relative loading functions for separate and combined sewer discharges have been derived from reported measurements of pollutant accumulation on streets and in sewers. Having arrived at this point it is now possible to discuss the relative efficiency and potential

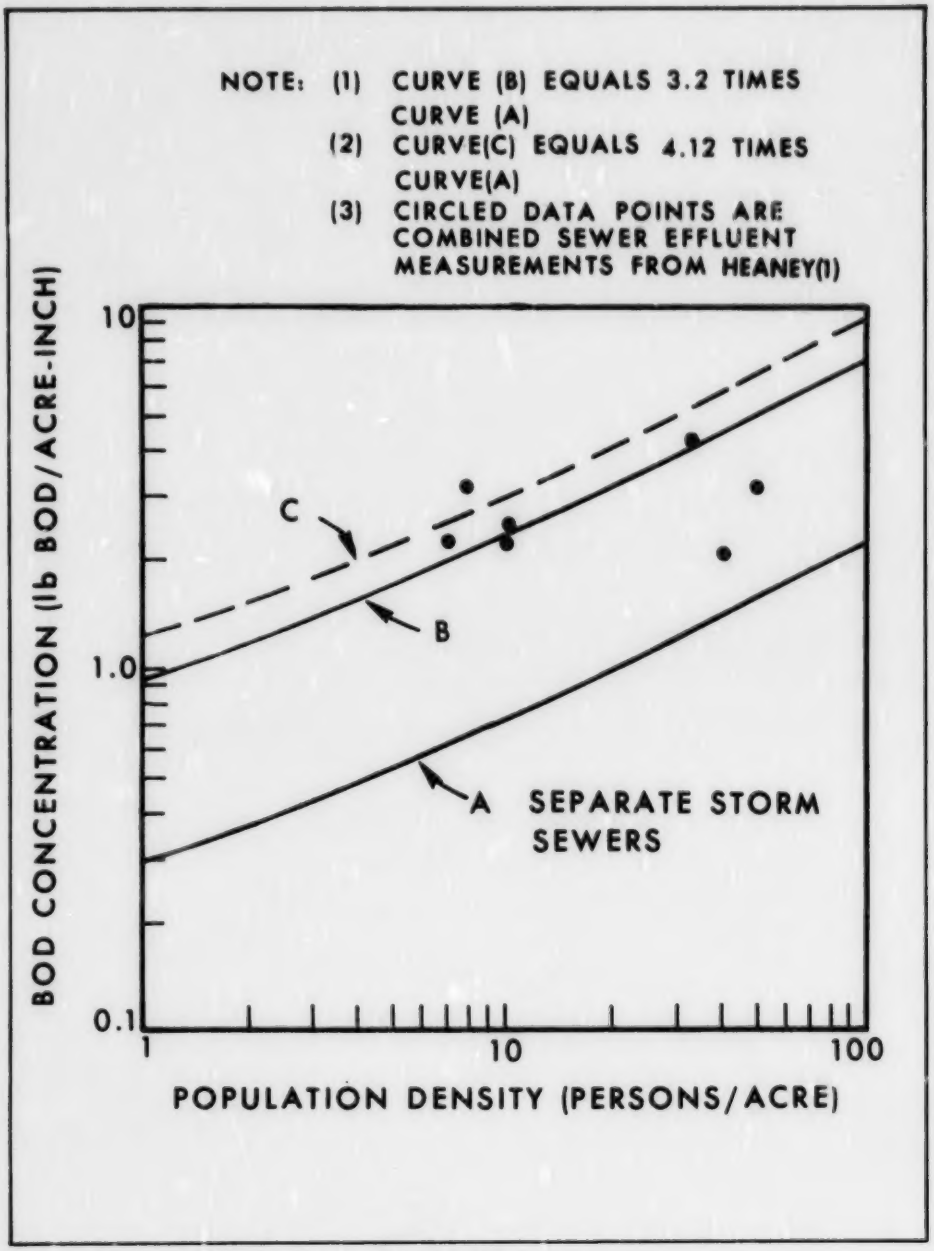

FIGURE G-4
BOD CONCENTRATION FOR SEPARATE STORM SEWERS AS A FUNCTION OF POPULATION DENSITY

TABLE G-1

URBAN AREA BOD LOADS (lb BOD/ACRE-YR) COMPUTED FROM STREET SWEEPING AND COMBINED SEWER SOLIDS BUILDUP MEASUREMENTS AS COMPARED TO ESTIMATES DETERMINED USING THE CHAPTER 3 METHODOLOGY

Community Population	Miles of Street/Acre, Figure G-2, Curve(B)	BOD Loading(lb BOD/Acre-yr)					
		Storm Sewers		Solids Flushed, Figure G-3 Curve (A)	Escaping Wastewater, Figure G-3 Curve (B)	Combined Sewers	
		Figure G-1, Curve(B)(APWA)	Figure G-1, Curve(A)(Ch.3)			Figure G-3, Curve (D)	Eq. G-4 X 3.2
3,000	0.0252	26.2	25.9	52.1	5.1	83.1	82.9
10,000	0.0195	20.3	27.4	40.3	7.3	75.0	87.7
30,000	0.0198	20.6	29.1	40.9	10.3	80.3	93.1
100,000	0.023	23.9	31.4	47.5	14.8	93.7	100.5
300,000	0.0285	29.6	33.9	58.9	20.6	113.4	108.5
1,000,000	0.038	39.5	37.2	78.5	29.8	145.5	119.0

costs of management techniques for controlling these pollutants.

G.3 Land Management Control Alternatives

G.3.1 Street Cleaning

The primary objective of municipal street cleaning practices is to enhance the aesthetic appearance of streets by periodically removing accumulated litter, debris, dust, and dirt. Such practices, however, do have an impact upon the amount and type of roadway pollutants which may be washed into receiving waters during runoff events. Consequently street cleaning is widely considered as a candidate management practice for reducing stormwater pollution loadings.

Streets are conventionally cleaned by manual or mechanically sweeping or by periodic flushing with water. The cleanliness of streets is also affected by the type and condition of pavement, the effectiveness of anti-litter programs, and the degree of air pollution (particulate) control in the urban area. The magnitude of the effect of these latter factors upon stormwater is difficult to assess except in general terms, due to the paucity of quantitative information. Litter control, primarily affecting large street debris such as cans, paper, bottles, is programmed entirely for aesthetic purposes and has little effect upon important water pollutants such as BOD, pesticides, heavy metals and small particulates. Streets in good condition are generally cleaner than those in poor condition; and concrete pavements tend to be cleaner than asphalt.

The purpose of this section will be to develop cost and effectiveness information for street cleaning techniques only. Because of the lack of good information no attempt will be made to develop cost/effectiveness relationships for litter control programs or pavement condition. Section G.3.6, however, provides an estimate of the impact of particulate air pollution control upon stormwater loads.

G.3.1.1. Street Sweeping

The most common methods of street sweeping include:

(1) mechanical (broom-type) sweepers
(2) manual

(3) vacuum sweepers

(4) combined vacuum and mechanical broom-type sweepers

Mechanical sweepers are most commonly used and, understandably, the majority of the currently available performance literature addresses this type of sweeper. Mechanical sweepers basically consist of a gutter and main broom which rotate at high speeds forcing the debris from the gutter and street surface onto a conveyor belt and subsequently into a hopper. Water is usually sprayed on the surface for dust control.

The effectiveness of mechanical sweepers is recognized to be a function of a number of factors, including: (1) particle size distribution of accumulated surface contaminants, (2) sweeping frequency, (3) number of passes, (4) equipment speed, and (5) pavement conditions.

Table G-2 displays the distribution of street surface pollutant fractions associated with various particle sizes (9). The interrelationship between mechanical sweeper efficiency and particle size is shown in Table G-3. The overall efficiency can be seen to be roughly 50 percent.

The effectiveness of street sweeping is also affected by the frequency of sweeping and the number of sweeper passes during each sweeping interval. As the sweeping frequency and number of passes increase the effectiveness of contaminant removal increases. The effect of sweeping frequency is described more fully in Part 2 of this appendix. For the purposes of the analysis of cost/effectiveness of mechanical sweepers in this section, however, the following relationship, developed by Sartor & Boyd (9), will be used:

$$\text{Efficiency} = 100\ (1 - M^*/M_o)\ (1 - e^{-0.7472P}) \qquad \text{(G-10)}$$

where M^* = ultimate residual dust-and-dirt, gm/sq.ft.

M_o = initial dust-and-dirt loading, gm/sq.ft.

P = number of passes made by sweeper

This relationship was determined from actual mechanical sweeper efficiency tests on naturally accumulated dust-and-dirt as well as a simulation developed to represent natural dust-and-dirt. Efficiency tests performed by equipment manufacturers and other research organizations were also cited in the studies.

TABLE G-2

STREET SURFACE POLLUTANTS ASSOCIATED WITH VARIOUS PARTICLE SIZES (9)

Measured Pollutant	Particle Size <43μ	43μ-246μ (% by weight)	>246μ
TS	5.9	37.5	56.5
BOD_5	24.3	32.5	43.2
COD	22.7	57.4	19.9
VS	25.6	34.0	40.4
Phosphates	56.2	36.0	7.8
Nitrates	31.9	45.1	23.0
Kjeldahl nitrogen	18.7	39.8	41.5
All heavy metals	51.2		48.7
All pesticides	73		27
PCB	34		66

TABLE G-3

INTERRELATIONSHIP BETWEEN MECHANICAL SWEEPER EFFICIENCY AND PARTICLE SIZE (9)

Particle Size (microns)	Sweeper Efficiency (% removal)
2,000	79
840-2,000	66
246-840	60
104-246	48
43-104	20
<43	15
Overall	50

It can be seen by Equation (G-10) that if the ratio of the ultimate residual divided by the initial loading is 0.05 the sweeping efficiency for one pass is 50%. Similarly, the efficiency of two-pass sweeping is 74% and the efficiency of three-pass sweeping is 85%.

The analysis of storm and combined sewer pollutant sources presented earlier in this appendix showed that about 25% of the separate storm sewer BOD load could be attributed to dust-and-dirt which can be swept from streets. This conclusion was based on the APWA (4) street sweeping experiments made in Chicago, which gave a weighted average street accumulation rate of 0.4 lb BOD/curb-mile/day. It should also be noted that the URS study by Sartor and Boyd (9) which resulted in Equation (G-10) also performed similar accumulation studies which produced significantly different values. The URS study measured street pollution in each of twelve cities for more than five land-use categories per city. The pollutant cover on a 40 ft. by 25 ft. section of street was measured by hand sweeping and flushing. The amount of BOD removed from these small sections averaged 14 lb BOD/curb-mile. Inquiries were made to determine the number of days since the street section was last swept. Based on this information, it was calculated that the street pollutant load averaged 4.5 lb BOD/curb-mile/day. This estimate is roughly ten times the APWA estimate of 0.4 lb BOD/curb-mile/day. Thus, the results of the two measurement programs are incompatible and cannot be averaged.

Because some logical value for loading is needed, the following evaluation must be made. The length of street swept by APWA was about 38 times the length swept by URS. Because of the greater amount of street sampled and the fact that URS did not sweep streets repeatedly but relied on local information on the time between regular sweepings it would appear that the APWA results form a more solid basis for estimating street pollutant loads.

Therefore, using the separate storm sewer loading relationship developed in Section G.2.2, and assuming that 25% of this load is on street surface and is available for removal, the maximum amount of BOD available for removal by street sweepers is 6-9 lb BOD/acre-year (25-37 lb BOD/acre-year times 0.25). If single-pass sweeping with an efficiency of 50% is used the load removal rate through sweeping will be 3-5 lb BOD/acre-year, or 12-14% of the separate

storm sewer load.

The cost of street sweeping has been reported by many sources and, according to Morris et al.(11), can vary from $2 to $14/curb-mile. Sartor and Boyd (9) cite a survey made by American City magazine where it was found that street sweeping costs varied from $2.18 to $8.42/curb-mile in 1970-71 dollars. The APWA report of street sweeping experiments in Chicago estimated the cost of single-pass mechanical street sweeping at about $10/curb-mile in 1968 dollars. The average cost of street sweeping in Cincinnati (1975) (12) was $8.40/curb-mile for mechanical sweeping and $45.68/curb-mile for hand sweeping. The cost of disposal of the sweepings was $3.36/cu.yd. The volume of sweepings collected was 0.6 cu.yd./curb-mile in Cincinnati which compares to a range of 0.18-0.56 cu.yd./curb-mile for the four cities surveyed by Sartor and Boyd (9). In Chicago the average volume of sweepings was 1.5 cu.yd./curb-mile. Since the amount collected in Cincinnati is about the average amount, the cost of disposal can be estimated at about $2/curb-mile (0.6 cu.yd./curb-mile x $3.36/cu.yd.) which, when added to the $8.40/curb-mile for sweeping, gives a total of $10.40/curb-mile.

The survey made by Sartor and Boyd (9) showed that the frequency of street sweeping computed by dividing the miles of street swept per year by the miles of streets scheduled for sweeping ranged from a low of 36 times/year in Baltimore to a high of 121 times/year in Phoenix. The average was 70 times/year, or every 5.2 days. Since the miles of street per acre range from a low of 0.019 to a high of 0.038, miles of street/acre can be multiplied by $/mile of street (2 x $10.40/curb-mile) times the average number of sweepings per year to find the cost in terms of dollars per acre per year. The cost of street sweeping is $28-$55/acre-year and this divided by the average loading removed (3-5 lb BOD/acre-year) gives the cost in dollars per pound of BOD removed as $7-$14/lb of BOD removed, for a single pass.

Vacuum street-sweepers may also be used. Three types of vacuum sweepers are available on the market today. The first is the so-called conventional vacuum sweeper which operates by sweeping the material from the path into approximately a one-foot windrow. This windrow, and only this windrow, is picked up by the vacuum. Dust problems are less evident than those created by mechanical sweepers; however, removal of fine particles is still questionable.

The second type features vacuum action over the entire path, assisted by a gutter broom. Still, the particulates which are embedded in the road surface do not receive sufficient agitation to become air-suspended and, therefore, the vacuum is unable to draw them into the hopper.

A relatively new concept is the regenerative air system. Sweepers of this type force air down onto the pavement, suspending the particles, which are then picked up by the vacuum suction. These sweepers may be the most efficient in removing fines.

The potential for overall debris control and, particularly, removal of dust-and-dirt by vacuum sweepers has been rather superficially reported in information currently available. An on-going EPA research investigation in San Jose, California is conducting a field examination of a variety of sweeper types, including vacuum sweepers (13).

Based on data from a pilot sweeping study, Field et al. noted that it could be feasible to improve removal efficiencies for various street surface contaminants through the use of sweepers employing a combination of broom and vacuum action (13). Under favorable conditions such equipment might be capable of removing up to 90% of deposited solids and perhaps as much as 67% of street surface BOD due to a greater efficiency in the removal of smaller particle sizes.

Costs of vacuum sweeping are reported to range widely from $2-$14/curb-mile. Regenerative air sweepers may cost from $3 - $10/curb-mile.

G.3.1.2 Street Flushing

Street flushing is a practice which is employed in many cities as an alternative to or in addition to street sweeping. Street flushers consist of an 800 to 3500 gallon water supply tank mounted on a truck or trailer which is equipped to allow water to be sprayed through three or more directional nozzles onto the street surface. As currently practiced, street flushing does not pick up contaminants but primarily serves to transport them from the center of the street surface to the gutter. The volume of water used is generally insufficient to transport the accumulated material to the nearest drain.

The relative surface cleaning efficiency of street flushing was compared to that of mechanical brush sweeping in the previously mentioned URS study (9). A mobile flushing unit with special high pressure, highly-effective, spray nozzles was used. The results of the tests which were conducted for similar mass loading, particle size, and surface type are shown in Figure G-5.

A comparison of the curves indicates that a street flusher of the type used in that study was a superior method for moving street contaminants, especially those in the dust-and-dirt fraction. Conventional street flushers, however, are not likely to be as effective as that used in the study.

Overall, unless greater than conventional flush volumes are used, street flushing will not on its own be an effective contaminant control practice. Even if street contaminants can be effectively washed into sewers, the practice will have impact only in areas which are served by combined sewers and also employ a sewer flushing program. The mere relocation of pollutants from street surfaces into sewers does not insure that they will not be subsequently washed into receiving waters during the next runoff event either in combined sewer overflows or direct discharge from separate storm sewer.

G.3.2. Sediment & Erosion Control

Soil erosion in urban areas is associated with construction of buildings, dams, sewerage facilities, roads, and new residential areas. Many adverse effects are caused by uncontrolled soil erosion. For example, sediment washed off denuded land can fill the pores of downstream land and destroy grass and other forms of vegetation thus reducing the infiltration capacity of the land and increasing the rate of runoff. Sediment will also clog storm sewers causing downstream flooding which can result in property damage. High sediment loads in natural streams make the water less fit for most human needs and increase the cost of potable water treatment. High sediment loads also can have a deleterious effect on aquatic life. The high runoff velocities resulting from the effects of erosion can erode stream banks causing further damage to the streams.

Although the acreage under construction is generally small compared to other forms of erodable land, the rate of erosion can be severe. For example, Ports (14) estimates that the rate of erosion from construction activity can

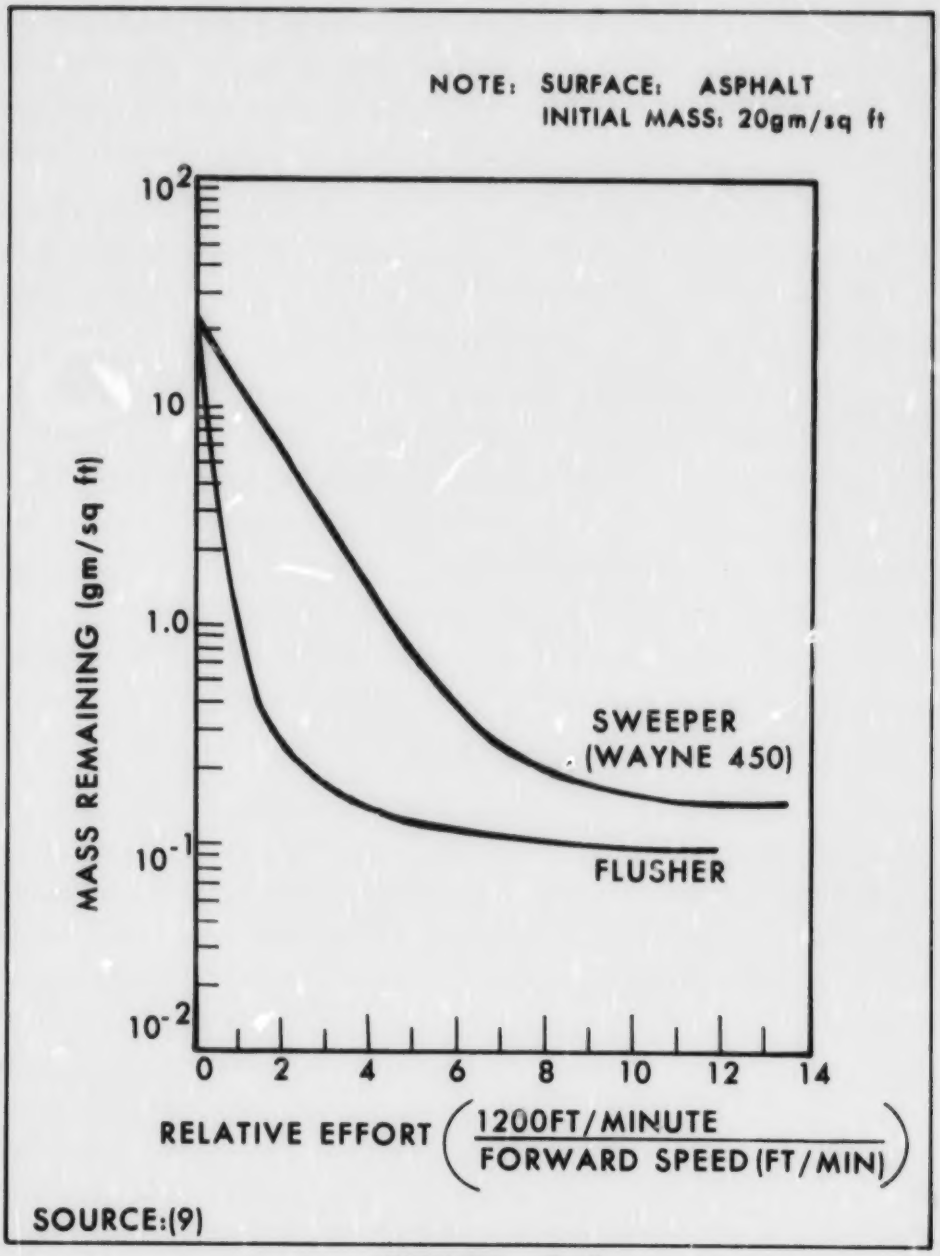

FIGURE G-5
COMPARISON OF CLEANING PERFORMANCES OF MOTORIZED STREET SWEEPING AND MOTORIZED STREET FLUSHING

be as high as 200 tons/acre-year as compared to about 0.2 tons/acre-year from forestland. Erosion from croplands is generally recognized as the single greatest source of sediment in natural streams. Ports estimates the rate of erosion from croplands to be in the range of 0.3 - 6 tons/acre-year.

In a study of nonpoint source pollution made by Midwest Research Institute in cooperation with Hittman Associates (15) the average erosion rate for construction was estimated as 75 tons/acre-year as compared to 0.4 tons per acre-year for forest and 7.5 tons/acre-year for cropland. This report also estimated the amount of land under construction at about 1.5 million acres as compared to 412 million acres of cropland. The U.S. Department of Agriculture (16) estimates that the total land area of the 50 states is about 2.3 billion acres and of this 1.1 billion acres is in farms and 333 million acres are in active croplands. Thus, if the erosion from croplands is assumed to be 6 tons per acre-year, the total sediment runoff for the U.S. is about two billion tons per year. Similarly, assuming the erosion from construction activities as 200 tons/acre-year, the total runoff for the U.S. is about 300 million tons per year. Thus, uncontrolled erosion from small land areas in urban construction activities might account for as much as 15% of the sediment runoff attributed to active croplands.

Other major sources of sediment are harvested forests and grassland. It has been estimated that both of these sources contribute about twice the amount estimated for construction activities (15). This report also estimated the sediment from urban construction activities at about three percent of the total runoff.

As much as 95 percent of the uncontrolled erosion which can occur at construction sites may be prevented using various combinations of relatively simple and inexpensive control techniques. These techniques were described in an Environmental Protection Agency report prepared by Hittman Associates (17), and range from the construction of sandbag and straw bale sediment barriers to use of diversion dikes, filter berms, flexible erosion control mats, gabions and chutes, flumes, and check dams. Table G-4 summarizes the calculated effectiveness of 10 erosion control systems (18).

TABLE G-4

PROMISING CONTROL SYSTEM AND EFFECTIVENESS

(After Reference 18)

System Numbers	Components	Percent Effectiveness
1	Seed, fertilizer, straw mulch. Erosion structures (normal). Sediment basins (0.04 ratio, and 70 percent of area)	91
2	Same as (1) except chemical (12 months protection) replaces straw	90
3	Same as (1) except chemical straw tack replaces asphalt	91
4	Seed, fertilizer, straw mulch. Diversion berms. Sediment basins (0.04 ratio and 100 percent area)	90
5	Seed, fertilizer, straw mulch. Downstream sediment basin (0.06 ratio)	93
6	Seed, fertilizer, chemical (12 months protection). Downstream sediment basin (0.06 ratio).	92
7	Seed, fertilizer, straw mulch. Downstream sediment basin using flocculants.	96
8	Same as (7) without straw mulch.	94
9	Chemical (12 months protection) sediment basin using flocculants.	94
10	Same as (9) with seed, fertilizer	96

Detailed costs for 25 erosion control methods were estimated in a report prepared for the Environmental Protection Agency by Engineering Science, Incorporated (18). Table G-5 summarizes the unit cost estimates developed, along with major assumptions used in preparing the estimates. The report also provides a method for estimating the overall cost of sediment control at specific sites as well as the damage costs which would result if no control were exercised.

It is difficult to generalize what a typical construction site erosion control system is and what its cost (e.g., $/acre) would be. The number, type, and cost of control measures are highly variable and very site and geographically specific because: (1) the erosion potential of sites vary widely with climate, slope, soil type, existing ground cover and other site conditions; (2) labor rates and material costs vary from region to region; (3) costs and feasible techniques are a function of project size, site terrain, and the type of construction activity (residential building, pipelines, highways, etc.); (4) it is sometimes difficult to distribute costs and benefits between sediment control objectives and aesthetic benefits (e.g., sodding and seeding practices, on-site ponds as sediment traps); and (5) techniques applied and their costs vary with the intended period of effectiveness, project life, and maintenance cost requirements.

Some attempts to evaluate average sediment control requirements for construction sites have been made. In 1972, for instance, Dow Chemical Co. performed an economic analysis for sediment control methods for watersheds undergoing urbanization (19). It utilized the Seneca watershed near Washington, D.C. as a model. The control practices included sedimentation basins, diversion berms, level spreaders, grade stabilization, sodded ditches, seeding and straw mulch. The total watershed system cost $1,125 per acre and controlled 91 percent of the erosion. It claimed that control systems with large sedimentation basins could boost control to 96 percent at a lesser total cost. Engineering Science (18) also estimated the cost of a "typical" erosion control program for a 2.95 acre commercial construction project. The control system included straw bale sewer inlet protectors, an earthen diversion dike, a straw bale diversion with a gravel weir, and a sediment retention basin. Using the unit cost values in Table G-5 the cost

TABLE G-5

COSTS FOR ON-SITE EROSION CONTROL MEASURES*

METHOD	UNIT COSTS California	Virginia	REMARKS
A) CONTROL STRUCTURES			
Gravel and Earth Check Dam	$1.84-0.83/cf	-	19 cf - 225 cf structures, resp.
Rock Riprap Check Dam	$7.00-8.17/cf	$5.99-$6.96/cf	56 cf - 300 cf structures, resp.
Concrete Check Dam	$22.15-8.04/cf	$20.03-$7.22/cf	51 cf - 891 cf structures, resp.
Concrete Chute	$32.45/ft 5.40/ft^2	$28.35/ft 4.72/ft^2	40 ft chute, 3 ft wide sides, 3 in thick
Diversion Dike (Interceptor Dikes)	$4.51/ft 0.48/cf	$3.70/ft 0.39/cf	405 cf dike,43 ft long
Erosion Check	$3.43/ft	$2.65/ft	150 ft jute mesh
Filter Berm (Filter Inlets)	$5.50/ft 0.39/cf	$5.11/ft 0.37/cf	810 cf gravel berm
Flexible Downdrain	$7.34/ft	$7.26/ft	300 ft unit with end connections
Flexible Erosion Control Mats	$1.18/ft^2	$1.11/ft^2	based on 33,000 ft^2 channel lining install.
Gabions	$3.34/ft^2 1.72/ft^2 1.41/ft^2	$2.76/ft^2 1.54/ft^2 1.26/ft^2	10 ft^{2}x1 ft install. 100 ft^{2}x1 ft " 1000 ft^{2}x 1 ft "
Level Spreader	$3.80/ft 1.91/ft 1.63/ft	$3.16/ft 1.57/ft 1.36/ft	15 ft long 44 ft long 78 ft long
Sandbag Barriers	$3.10/bag 12.40/ft	$2.44/bag 9.76/ft	filling & placing 180 bags/day~45x4' barrier
Sectional Downdrain	$14.55/ft 10.91/ft	$11.85/ft 9.13/ft	44 ft unit 234 ft unit
Sediment Retention Basin	$0.51-0.39/cf	$0.42-0.33/cf	earth structures 30 to 40 ft long and 6-8ft h
Straw Bale Inlet Protection	$55/inlet	$46/inlet	
Straw Bale Barriers	$3.93/ft	$3.31/ft	2 ft bales x one high
B) GROUND COVERS			
Excelsior Mat	$12,000/ac	$10,200/ac	includes seed & fertilizer
Jute Mesh on One-Acre Plot	$7,700/ac	$6,700/ac	
Straw or Hay (blower applied)	$1,200/ac	$1,100/ac	
Woodchips	$8,000/ac	$7,200/ac	3" cover
4" Square Plugs of Sod	$11,300/ac	$10,300/ac	includes seed & fertilizer
Sodding	$14,800/ac	$14,300/ac	
Chemical Soil Stabilizer	$1,300/ac	$1,250/ac	
Hydromulch	$858-434/ac	$738-373/ac	1 acre - 30 acre job, resp.

*All costs in 1972 dollars

was estimated at $1,340/acre (California) and $1,110/acre (Virginia).

Engineering-Science also concluded that the technique which appears to be the most cost-effective is hydromulching. Hydromulching is a technique where wood chips are mixed with grass seed, fertilizer and water to form a slurry which is then sprayed on the denuded land. The wood chips tend to hold the soil and encourage the growth of the grass which then acts as an effective erosion deterrent. The cost of hydromulching in 1973 dollars ranges from about $850/acre when only one acre is treated to a low of about $344/acre when the land area is 30 acres or greater. For the example commercial construction site described above, the use of hydromulching would add $720/acre (53.7%) and $680/acre (6.13%) to the erosion control program costs in California and Virginia, respectively.

Cost estimates have also been made in various studies for determining the economic, aesthetic, and environmental damages which may result from not controlling erosion. The Dow Chemical Study estimated that miscellaneous damages of erosion from construction sites could reach $1,500 per acre (19). These damages included: a need for turbidity control in water treatment; dredging costs downstream; flooding; adverse effects to commercial and recreational fishing; boating and aesthetics. Engineering Science also made cost estimates of removing silt from homes, streets, stream channels, and in domestic water treatment (18). Estimated costs for sediment removal are shown in Table G-6. The study concluded that the cost of controlling erosion at construction sites is in most cases significantly less than the cost of correcting the damage caused by uncontrolled erosion.

G.3.3 Site Runoff Control

On-site or upstream runoff control refers to storage for detention (short term) or retention (long term) of runoff prior to its entry into a drainage system. In urban areas, roofs of structures represent a large part of the impervious surfaces which increase runoff. In many communities with combined sewers, the drainage from such roof areas is discharged into the sewer system via the single property sewer connector. The pollution potential of roof runoff consists of particulate air pollution dustfall, tree leaves, and bird droppings. Other impervious surfaces such as paved parking lots,

TABLE G-6

COSTS FOR SEDIMENT REMOVAL MEASURES

(Adapted from Reference 18)

Removal Measure	Unit Costs	
	California	Virginia
Sediment Removal from Streets	$8/cy	$6.60/cy
Sediment Removal from Basements	$77/cy	$65/cy
Sediment Removal from Storm Sewers Bucket Line Cleaning	$144/cy	$122/cy
Sediment Removed from Storm Sewers Rodding & Hydraulic Flushing of Storm Sewer	$68/cy	$62/cy

plazas, etc., having their own classes of pollutants, generally drain into the municipal sewerage system, causing sudden increases in pollutional load and wastewater volume during a storm event. In areas of lesser population densities, although the absolute and relative magnitudes of impervious surfaces decrease, similar effects of a storm event exist but to a lesser degree. In the latter situation in addition to runoff from impervious areas, surface runoff from pervious areas also contributes a pollutional load, generally erosion solids; and results in a sudden incremental volume to either the sewerage system or to the natural drainage network of the area.

Detention - In its simplest form, detention means capturing stormwater and controlling its release rate in order to decrease downstream peak flow rates. Oftentimes, on-site storage does or can be designed to provide for the dual or multi-benefits of aesthetics, recreation, recharge, irrigation, or other uses. For example, groundwater supplies are replenished by detention-recharge. However, the potential for groundwater pollution must also be considered. The design essentials include a contained area that allows the stormwater to pond and a release structure to control the rate at which the runoff is allowed into the drainage system. The release structure is usually a simple construction, such as a small-diameter pipe draining the basin or an orifice plate placed at a sewer inlet. The capacity of the pipe or orifice limits the flowrate to a level acceptable to the downstream system. Where the depth of ponding has to be limited, the release structure will have an automatic overflow to prevent excessive ponding.

Successful variations of detention that take advantage of facilities primarily used for other purposes are ponding on parking lots, plazas, and recreation and park areas. The fundamental approach is the same as for other forms of detention but low cost is implied.

Surface ponding is the most common form of detention being used by developers. In most cases the facilities are carefully planned so that the ponding area is a dual-use facility for recreation and athletics that enhances the value of the site when dry. Variable level ponds have a permanent water level during dry weather and increased holding capacity during storm conditions. The permanent lakes have aesthetic and recreational appeal which increases lot values. Basins that are dry between storms are often designed to be

used as baseball fields, tennis courts, and general open space. Parking lots can be made to serve as low-depth storage ponds by sloping the side and constructing drain outlets. Side slopes are restricted to about 4 percent for traction in the winter, and the pond depth is limited by the need for people to reach their vehicles. Obviously, a truck terminal lot can be allowed to pond to a greater depth than a supermarket lot.

Other variations of detention that have proven successful for metropolitan application are ponding on plaza areas and ponding on roof tops. The basic approach is the same as for other forms of detention. The outlet from the ponding area must be constructed to allow runoff to accumulate during peak storm conditions. The depth that can accumulate on plazas must be limited to approximately 3/4 inch because of pedestrians, but it is possible to design plazas so that portions can be flooded without inconvenience. Metropolitan roof tops provide an excellent opportunity for stormwater detention. Most are flat, watertight, and structurally designed to take loads greater than that of ponded stormwater. It adds very little to the cost of a new building to ensure structural conditions for ponding. The detention is controlled by a simple drain ring set around the roof drains. As the roof begins to pond, flow is controlled by orifices in the ring; extreme flows overflow the ring to prevent structural damage to the roof.

Retention - The precipitation/infiltration process is the most important method of replenishing the groundwater reservoirs that serve as potable water supplies for many areas of the county. The decreased infiltration and increased water demand caused by urbanization will stress groundwater supplies unless recharge areas are set aside. Although large-scale urban stormwater recharge programs have not been implemented because of potential groundwater pollution, onsite retention and recharge has been developed for small watersheds. Retention basins are usually variable-depth ponds designed with no outlet or only a bypass for exceptional flow conditions. They fill during storms and help maintain the groundwater during dry intervals. If groundwater protection is important, heavily polluted runoff is not used for recharge. The pollution control value is in the decreased volume of runoff entering downstream systems, as was discussed in the previous section.

Retention is also practiced as controlled onsite storage where groundwater recharge is not important. In a typical example, the California Division of Highways has built retention basins to dispose of highway runoff in the San Joaquin Valley. These basins were developed from 1- to 6-acre depressions that had originally been excavated for embankment material. Infiltration capacity is sometimes improved by excavating 6- to 10-foot deep trenches or vertical drains and backfilling with porous material. Maintenance is minimized by providing low-velocity channels ahead of the basins to help settle suspended particles. The areas are scarified once a year to decrease the surface clogging effects of organic solids. Advantages of the ponds include total containment of the highway runoff pollutants and the recreational asset to local cities that can result from an overall plan to landscape the basins as additional park land. The alternative to retention is to construct sewers to carry the runoff to receiving waters. Therefore, the economic advantages depend on the size and length of sewer that would be required.

Design Considerations - The acceptability of onsite storage as a pollution control alternative depends on the mitigation of apparent adverse factors, including the safety hazard to children, maintenance difficulties, mosquito breeding, algae growth, the land area required, possible poor appearance of dry ponds, and the responsibilities of ownership.

Safety - The safety features depend on the secondary use of the facility. Obviously, a dual-purpose recreational lake cannot be fenced to prevent access. Typical safety features include shallow bank slopes, fences, and outlet guards.

Maintenance - Debris removal, care for the landscaping, and maintenance of the outlet structure are all part of the routine operation of a retention facility.

Mosquito breeding and algae growth - Both mosquito and algae problems can be eliminated from dry basins by ensuring that the areas dry out completely between uses. For permanent ponds, these problems are more difficult to control. Mosquito breeding can be upset by controlling grass at the shoreline, varying the water depth every few days, or stocking the ponds with larvae-eating fish.

Land area required - The best way to overcome objections to land set aside as a detention pond is to recognize that the area can be an asset as open space. Housing near greenbelts and pond areas usually has a higher market value if the open space is aesthetically designed.

Poor appearance of dry ponds - Detention ponds are most presentable when a grass cover is kept on the basin slopes and floor. Grasses can be grown that will withstand periodic flooding. If retention basins contain water for long periods of time or need to be vegetation-free for better infiltration, appearance objections may be overcome by sight barriers such as trees.

Responsibility of ownership - In most cases the responsibilities of operation and ownership should be assumed by a public agency. The equipment, manpower, and expertise required for operation and maintenance is beyond the abilities of homeowner associations and developers.

Effectiveness and cost - The effectiveness of storage ponds in reducing pollutional loads can be estimated from the following exercise. In Chapter 16 of the Soil Conservation Service Hydrology Handbook (20) the following relationship was developed based on the use of a triangular hydrograph and a number of heuristic constraints:

$$q_p = 484\ A\ Q/(D/2 + 0.6\ T_c) \qquad \text{(G-11)}$$

q_p = peak rate of runoff, CFS

A = catchment area, sq. miles

Q = amount of rainfall, inches

D = duration of rainfall, hrs

T_c = time of concentration, hrs

In the context of runoff storage it is seen in the equation that the peak rate of runoff (q_p) is directly proportional to the amount of rainfall (Q) and the size of the catchment area (A). If, for example, the runoff from 25% of the urban drainage area flows into storage ponds, the peak runoff rate will be reduced by 25%.

In order to estimate the effect that residential storage ponds have on reducing combined sewer overflows the following computations must be performed. The fraction of the drainage area from which runoff flows into storage ponds

is called Fa, and K is the ratio of treatment plant capacity (TPC) to dry weather flow (DWF). When storage ponds are used, a corrected value for K (called K*) can be computed as follows:

$$K^* = (K - 1) / (1 - Fa) + 1 \qquad \text{(G-12)}$$

This procedure has been followed for the situation in which 25% and 40% of the land area drains into ponds, and the results are shown in Figure G-6. This figure shows that while the use of on-site storage does have a potential for reducing the annual hours of overflow, the reduction is strongly dependent on the K ratio. If, for example, the K ratio is 10 and 40% of the land area drains into ponds, the number of hours that overflows occur per year are reduced from 65 hours/year to 46 hours/year. This is a 29.2% reduction in annual overflow hours and a 40% reduction in runoff volume. However, a more representative raio (K) of TPC:DWF ratio is 4. At K = 4, there is a 12% reduction in the number of hours overflow per year when 25% of the drainage area runoff is impounded, and a 21.4% reduction in hours overflowing when 40% of the land area drains into ponds.

The feasibility of using neighborhood ponds for storage of runoff depends on the topography of the community and on the availability and cost of land. Although no general appraisal of the cost/effectiveness of ponds is applicable to all situations, one economic aspect of surface ponding is derived from the savings realized by eliminating the construction of a conventional sewer project. As examples of the cost magnitude involved several surface ponding sites are listed in Table G-7 showing the cost comparison between estimates for drainage systems using ponds to decrease peak flows and estimates for conventional strom sewer construction.

In the absence of technical feasibility and economic estimates to the contrary, the following type of reasoning can be used when the characteristics of the specific community are known. If the ponds are sized to contain the runoff from a total of eight inches of rain, the range of water level for the ponds is two feet, and the volumetric runoff coefficient is 0.25, the ratio of drainage area to ponds area will be 12. Thus, if 25% of the surface drains into the ponds, the pond area will be 2.1% of the drainage area. The cost of ponds was estimated by Black and Veatch (22) as roughly

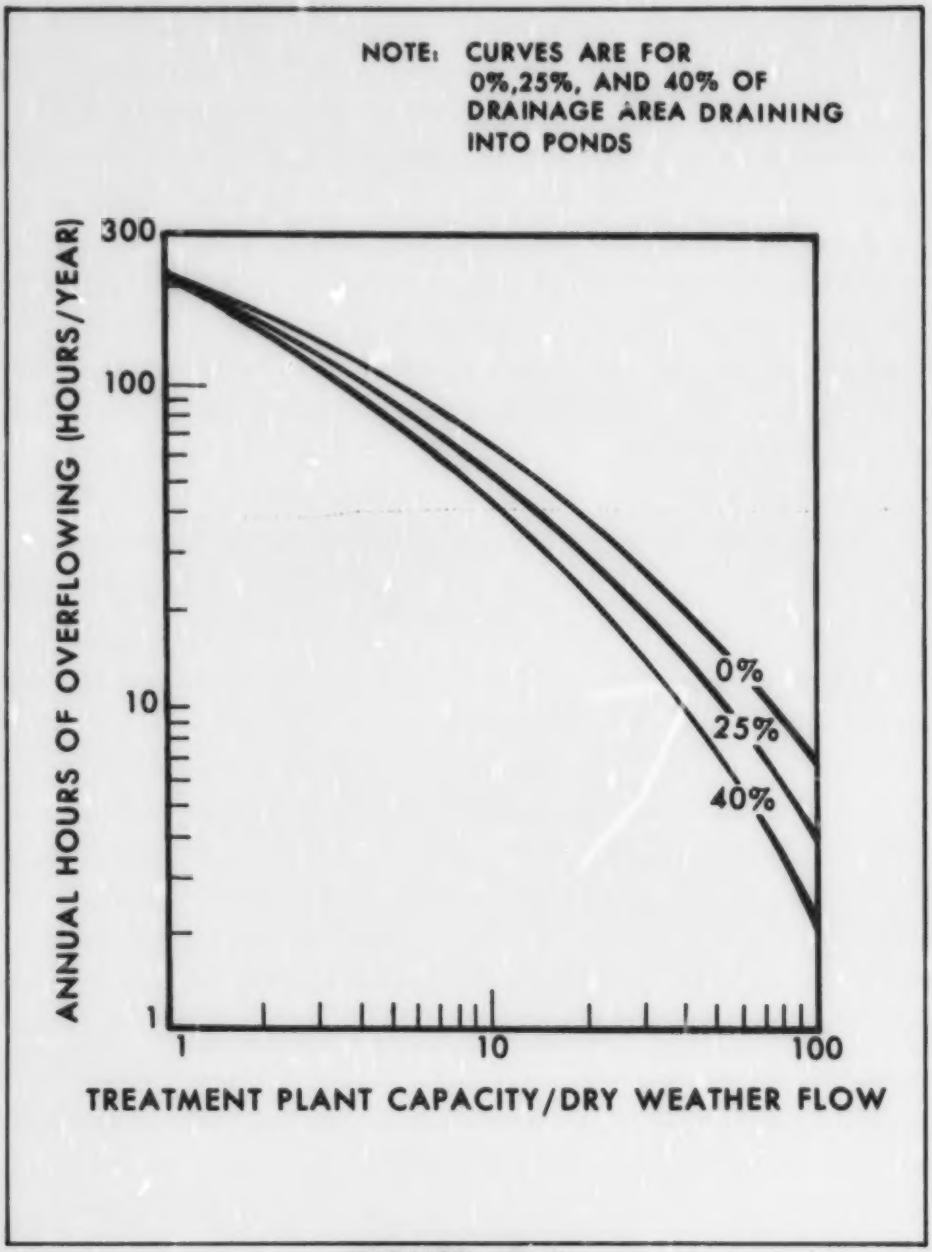

FIGURE G-6
EFFECT OF UPSTREAM STORAGE ON ESTIMATED ANNUAL HOURS OF OVERFLOW VERSUS TREATMENT PLANT HYDRAULIC CAPACITY

TABLE G-7

COST COMPARISON BETWEEN SURFACE PONDING TECHNIQUES AND CONVENTIONAL SEWER INSTALLATION (21)

Site	Description	Cost estimate, $	
		With Surface Ponding	With Conventional Sewers
Earth City, Missouri	A planned community including permanent recreational lakes with additional capacity for storm flow	2,000,000	5,000,000
Consolidated Freightways, St. Louis, Missouri	A trucking terminal using its parking lots to detain storm flows	115,000	150,000
Ft. Campbell, Kentucky	A military installation using ponds to decrease the required drainage pipe sizes	2,000,000	3,370,000
Indian Lakes Estates, Bloomington, Illinois	A residential development using ponds and an existing small diameter drain	200,000	600,000

$15,000/acre in current dollars. If the land cost is taken as $5000/acre the total cost of ponds will be $20,000/acre. In terms of dollars per acre of total drainage area this is $500/acre. Amortizing the ponds at 6% over a life of 50 years the cost of owning the ponds will be $31.72/acre-year. If the pollutional load of the runoff is 30 lb BOD/acre-year and the ponds reduce the load by 12.5% to 25% the cost of BOD reduction will be in the range $4.23 to $8.46 per lb BOD removed. Thus, it appears that the use of neighborhood ponds for storage of runoff may be a feasible pollution control alternative.

As mentioned in the beginning of this section on on-site control of runoff, another alternative for reducing the amount of combined sewer overflowing is removal of roof downspout drainage from the combined sewer. If downspout drainage is directed onto the lawn area a major fraction of the rainfall runoff from roofs is likely to infiltrate into the ground. In the ten acre area studied by APWA (4) and Tholin and Keifer (23) about 31% of the area of the individual building lots was roof area. About 17.2 percent of the ten acre area was covered by paved streets and alleys. The pervious fraction including roofs, streets, and alleys was 0.379. If the runoff coefficient for lawn area is taken as 0.1 and the runoff coefficient for streets and roofs is taken as 1.0 the composite runoff coefficient with downspouts emptying into the combined sewer will be 0.44 as compared to 0.25 when the downspouts are directed onto the lawn area. This represents a 43 percent reduction in the runoff coefficient. Since some of the roof drainage will fail to infiltrate and perhaps flow ultimately into the combined sewer this estimate is an upper limit. It might be expected that removing downspouts might reduce the annual hours of overflow by about 15-25 hours/year and effect a reduction in total runoff volume between 25-40%. This simple and inexpensive method appears to have significant potential for preventing combined sewer overflowing and thus reducing the amount of pollution which reaches the stream. The cost will be primarily measured in terms of inconvenience to homeowners.

G.3.4 Porous Pavement

The use of porous asphalt paving to improve infiltration of precipitation at the source prior to concentration is a technique which is still in the developmental stages. Its purpose is to increase infiltration and to reduce flood peaks. It is also used to reduce the need for separation of storm sewers and sanitary sewers, especially in cases where the system is already overloaded. The advantages of using this management technique are given as follows: (24)

1. Reduces the total volume of runoff from paved areas.
2. Can reduce the peaking effect of local floods.
3. Enhances groundwater supply.
4. Its use can often result in savings resulting from the elimination of the need for storm sewers and curbing.
5. An improvement in the quality of roadside vegetation may be seen due to improved water availability in the soil.
6. As contrasted with conventional paving materials, there would be some preservation of natural drainage patterns in the urban setting.

A number of potential disadvantages are given as follows: (24)

1. It has not been clearly established that the filtering effect of the sub-base results in a significant improvement in the quality of the runoff if that runoff is polluted. In those instances where the runoff can be severely polluted by substances which could reduce the quality of the groundwater, it is not recommended that porous pavement be used.
2. Under certain circumstances the surface may become clogged and its permeability reduced or eliminated. Examples of such conditions are inadequate maintenance, rain on a frozen surface, and certain conditions during snowmelt. These circumstances can all result in runoff.
3. When the usual accessories of conventional paving are required (curbs, etc.) the higher construction costs may affect other economic considerations.

4. A special maintenance program is required.

The feasibility of using proous pavement in urban areas to reduce the rate and volume of runoff was examined by Thelen et al. (25) of the Franklin Institute Research Laboratories, Philadelphia, Pennsylvania. They concluded that an open-graded asphalt concrete would be the most suitable material for porous pavement because of its superior physical characteristics, its low cost, and its ability to be laid by conventional paving methods. Other types of porous pavement such as bricks assembled on rods with spacers, rubber sheeting over honeycomb, or bricks with lugs to control spacing have been suggested and might be appropriate for parking lots or aircraft runways.

The potential advantage of using porous pavement appears to be good but many problems have yet to be fully resolved. For example, water which infiltrates into the surface and the base course must be able to slowly infiltrate into the subgrade. Thelen et al. estimate that the coefficient of permeability must be at least 0.01 ft/day; characteristic of a sand-clay mixture. Freeze-thaw laboratory experiments were performed by Thelen et al. and it was concluded that the asphaltic porous surface would be able to hold its strength after 265 freeze-thaw cycles. However, a more realistic way of testing the porous pavement would be to lay a test length of highway in a northern climate. The hope is that aerobic bacteria which should be able to live in the surface and base courses of the pavement will help to rid the open spaces of organic material which will tend to clog the interstices. However, much of the dust-and-dirt which accumulates on streets is inorganic and the possibility of gradual clogging has not been adequate investigated.

As compiled by Delaware University, Water Resources Center, the design criteria and specifications are as follows: (24)

Porosity of Asphalt: Lab studies at the Franklin Institute (25) revealed that a porous asphaltic concrete containing 55% asphalt by weight and aggregate graded to allow water flow of 76 inches per hour to be optimal porous road material.

Aggregates: The aggregates used for porous pavement construction should satisfy ASTM-C-693-71 except in requiring the gradation to be the "open-graded type", but also requiring a soundness test ASTM-694-62.

As observed in Table G-8, the surface thickness and the thickness of the aggregate base course depend on the load bearing capacity of the subgrade soil and the traffic volume carried. The base thickness ranges from 6 inches for light traffic to 22 inches for highway traffic. The surface thickness ranges from 4-7 inches. The reservoir capacity of the pavement ranges from 2.4 inches of rain at a 6-inch base thickness to 7.65 inches of rain at a base thickness of 22 inches. Thus, it can be seen that even with 6 inches of base the reservoir capacity is sufficient to store a very large fraction of the storms. Since streets and highways cover about 28% of the developed urban area it is not unreasonable to visualize porous pavement as having an effect similar to ponds holding the runoff from 28% of the drainage area.

Capacity of Subsurface Reservoir: For the Philadelphia area a subsurface reservoir depth of 16 inches is recommended, capable of providing temporaty storage for a design storm of 5.4 inches per hour. Maximum daily precipitation is the critical factor and base courses of 7 inches are recommended for areas with 3 inches maximum precipitation per rainy day, 14 inches thickness for 6 inches maximum daily precipitation.

Soil Permeability: A soil capable of absorbing 5 inches of rainfall in a 10-day period, having a permeability of over 0.042 ft/day is adequate.

Maintenance: The surface of porous paving must be cleaned regularly and after each storm using a vacuum-type road sweeper to keep surface porosity as great as possible.

Additional design criteria and specifications are:

1. On slopes in excess of 5% porous paving should not be used. On shallower slopes a gravel-filled swale takes runoff and base flow.

2. Where soil is poorly drained, trench drains may be used at edges of porous paving areas or in a lattice work to lead excess water off-site.

TABLE G-8

REQUIREMENTS FOR SURFACE AND BASE COURSE AND SUBSURFACE CAPACITY

Traffic Load	CBR[1]	DTN[1]	Surface Thickness (inches)	Base Thickness (inches)	Reservoir Capacity (in. of rainfall)		
					Surface	Base	Total
Light	2	1	4	6	.60	1.80	2.40
	2	10	4	12	.60	3.60	4.20
	2	20	4-1/2	13	.66	3.90	4.56
Medium	2	50	5	14	.75	4.20	4.95
	2	100	5	16	.75	4.80	5.55
Heavy	2	1000	6	20	.90	6.00	6.90
	2	5000	7	22	1.05	6.60	7.65

Notes: 1. DTN = Design Traffic Number; CBR = California Bearing Ratio

2. A minimum surface thickness of 4 inches is used regardless of DTN

3. The estimated volume of voids in the base aggregate is 40%.

4. Frost bearing: If the combined surface and base thickness is less than anticipated frost penetration, additional base is required.

3. A single "V" drain may be used to intercept longitudinal base flow during exceptional storms or to divert base flow from fill.

4. In areas where grading puts exceptional pressure on areas of subsurface reservoirs, excess water can be removed via a tile drain system.

5. Additional informtion on specifications is found in the EPA report "Investigations of Porous Pavements fo· Urban Runoff Control" (25).

Cost Guidelines: Under contract, the University of Delaware built a 3100 sq. yd. porous parking lot in 1973. The cost of two inches of asphalt topping was $5.50 per sq. yd. as compared to $3.33 per sq. yd. of conventional asphalt.

An estimate of costs of conventional and porous pavements prepared by the Franklin Institute in 1972 and updated to January, 1975 is shown in Table G-9.

TABLE G-9

COSTS OF CONVENTIONAL AND POROUS PAVEMENTS
($ per sq. yd.) (26)

Type	Porous Pavement		Conventional Pavement	
	Range	Average	Range	Average
Parking Lot	8.43-8.53	8.48	4.87-7.75	6.31
Residential Street				
Low Capacity	8.44-8.49	8.47	6.40-12.80	9.60
High Capacity	8.25-8.75	8.51	11.13-16.13	13.64
Business Street				
Suburban	8.87-9.29	9.04	9.20-13.20	11.20
City	9.32-11.09	10.21	18.93-29.60	24.27
Rural Road	8.01-11.09	8.59	9.65-17.60	12.27
Highway, 2-lane	9.07-10.56	9.81	11.39-27.27	19.33

To summarize, the use of porous pavement has many potential advantages such as reducing the rate of runoff, replenishing the ground water supplies, eliminating the need for curbs and storm sewers for highway drainage, improving safety by eliminating the formation of puddles during heavy rains,

and relief of flash flooding. On the other hand, questions such as the susceptability of the pavement to clogging, the durability of the pavement during winter weather under heavy traffic loads, and the problem of adequate drainage into the subgrade remain to be satisfactorily resolved.

Although there may be cost savings due to elimination of curbings and stormwater drainage systems when porous pavement is used, the placement and sizing of storm sewerage systems is generally determined by ordinance in most municipalities. Porous paving is a relatively new development, and few local regulations permit its use. Where it can be used, however, regulations may not permit any reduction in the size of storm drains.

The cost of porous pavement is roughly equivalent to the cost of conventional pavement but significantly less than conventional pavement equipped with storm drains. The potential advantage of using porous pavement appears to be good but many problems have yet to be fully resolved.

G.3.5 Chemical Use Control

Most surfaces in an urban setting are treated, altered, or otherwise exposed to chemicals either applied by man or resulting directly from man's activities. The urban environment accumulates the refuse from man's activities and the process of urbanization increases the accumulation. Contaminants of many kinds accumulate on urban surfaces from dustfall, littering, leakage from street vehicles, and many other sources. Particles discharged into the air from industrial, commercial, or construction activities will either settle to the ground if they are too heavy to remain airborne or will be washed out in the next rainfall. On occasions these washouts can occur many hundreds of miles distant from the original source of the air contamination. Streets in industrial areas have been found to be particularly contaminated, containing soluble compounds of heavy metals and organics. Concentrations of metals in runoff have been found to be ten to one hundred times greater than in sanitary sewage, and contain copper, cadmium, zinc, and lead in high enough levels in street runoff to kill certain aquatic organisms (27).

Traffic residuals are another major source of chemicals in stormwater runoff. Some pollutants such as lead compounds are released to the atmosphere and then settle to the ground. Indicative of this is the high correlation

between traffic density and lead fallout measured in dustfall. Quantitatively, less than 5 percent by weight of the traffic-related deposits originate directly from motor vehicles, but these pollutants are among the most important by virtue of their potential toxicity. Spills or leaks or motor vehicles lubricants, antifreeze, and hydraulic fluids result in grease, petroleum and n-paraffins in runoff. Lead and lead oxide stem from fuels and the wear of tires. Zinc loadings may, in part, result from motor oils. Wear of engine parts allows the deposition of copper, nickel, and chromium. Finally, asbestos fibers are left from the wear of clutch and brake linings.

In addition to highly active industrial and commercial centers, urban surfaces remote from these activity centers are also sinks and sources of chemicals. Suburban sidewalks, planter strips, lawns and backyard garden plots, driveways, and roadside green belts, etc. are contributory to the total pollutional load of runoff. Deicing salts used on streets and highways contribute not only salt contamination in acute and chronic doses, but also are the source of ferric ferrocyanide, sodium ferrocyanide, chromate, and phosphate which are used as special additives in much of the highway salt in common use. High nutrient levels from fertilizer application on lawns and garden plots, and specific pesticides resulting from tree spraying, weed control, and insect control on public and private lands have been noted.

Nutrients - Data on loading intensities of nutrients found on street surfaces have been presented by Sartor and Boyd (9), and shown in Table G-10.

As noted in the report, the strength values vary somewhat from one land-use category to another, but only over a moderate range. These data, which are based on the analysis of samples from numerous cities, imply that all street surface contaminants are similar in nutrient composition from site to site.

Pesticides - The widespread and often indiscriminate use of pesticides is a cause for concern due to their toxicity and persistence in the environment. Although it is difficult to identify specific sources of pesticides, particularly at a sublethal chronic level, reports of fish kills and subsequent chemical analyses do substantiate the transport of this class of toxic compounds to receiving waters. Sartor and Boyd (9) reported the loading

TABLE G-10
NUTRIENTS IN STREET SURFACE CONTAMINANTS
VARIATION WITH LAND-USE CATEGORY (9)

	STRENGTH (% by weight)	LOADING INTENSITY (lb/curb-mi)	LOADING INTENSITY (lb/1,000 sq ft)
Phosphates			
Residential	0.113	1.07	12.3
Industrial	0.142	3.43	39.4
Commercial	0.103	0.29	3.41
Kjeldahl Nitrogen			
Residential	0.218	2.04	23.8
Industrial	0.163	3.94	67.1
Commercial	0.157	0.45	5.17
Nitrates			
Residential	0.0064	0.063	0.70
Industrial	0.0072	0.178	2.00
Commercial	0.0600	0.172	1.96

Note: The term "strength," as used here, refers to the amount of contaminant contained in the dry solids collected from the street surface (on a weight basis), i.e., a phosphate value of 0.1 percent would be equivalent to 1 lb of phosphate per 1,000 lb of sample.

intensities of pesticides found in street surface samples which they tested (Table G-11), and the pesticide concentration measured in the total solids on the streets tested, distinguishing among residential, industrial, and commercial land-use activities (Table G-12).

Additional clarification of the data indicated that DDD, DDT, and dieldrin tended to be associated with the finer particles (DDD:60 wt %, < 246 μ; DDT & dieldrin:80 wt %, < 246 μ) found on the streets.

Heavy Metals - As was the case in the discussion of pesticides, interest in the occurrence of heavy metals in urban runoff is not so much in the BOD implications of their presence but rather because of their potential toxicity in receiving streams. Data from Sartor and Boyd (9), presented in Table G-13

TABLE G-11

PESTICIDE LOADING INTENSITIES

(10^{-6} lb/curb-mi)

	p,p'DDD	p,p'DDT	DIELDRIN	ENDRIN	LINDANE	METHOXY-CHLOR	METHYL PARATHION	PCB's	TOTAL OF ALL PESTICIDES AND PCB's
San Jose I	67	110	11	2	17	0	20	1,200	1,427
San Jose II and Seattle	120	170	27	0	0	0	0	1,100	1,417
Phoenix II, Atlanta and Tulsa	34	13	24	0	0	0	0	65	136
Milwaukee	0.5	1.0	10	0	3.1	8500	0	3,400	12,000
Bucyrus	83	60	17	0	0	1600	0	650	2,451
Baltimore	100	30	3.0	0	0	170	0	1,000	1,300

TABLE G-12

PESTICIDE CONCENTRATIONS IN TOTAL SOLIDS (ppm) (9)

	p,p-DDD	p,p-DDT	DIELDRIN	ENDRIN	LINDANE	METHOXY-CHLOR	METHYL PARATHION	PCB's
Residential								
San Jose I	0.082	0.15	0	0	0	0	0	0.81
Milwaukee	0	0	0.009	0	0	2.5	0	2.0
Baltimore	0.11	0.030	0	0	0	0.19	0	0.99
Industrial								
San Jose I	0.060	0.091	0.031	0	0.031	0	0.037	1.5
Milwaukee	0	0	0	0	0.001	3.6	0	2.0
Baltimore	0.020	0.020	0.018	0	0	0	0	1.0
Commercial								
San Jose I	0.040	0.030	0	0.058	0	0	0	0.60
Milwaukee	0.020	0.031	0	0	0	1.8	0	0.99
Baltimore	0.020	0.031	0	0	0	0	0	0.51

shows the heavy metals loading intensities (in pounds per curb mile) as distributed among the major land-use categories.

TABLE G-13

HEAVY-METALS LOADING INTENSITIES
(lbs/curb-mile)

Land Use	Chromium	Nickel	Lead	Copper	Zinc	Mercury
Residential	2.0	0.5	15.7	4.8	16.8	4.8
Industrial	4.7	2.2	14.8	7.7	29.2	0.8
Commercial	1.0	0.3	3.5	1.8	3.0	1.5

The authors noted in their presentation that the samples collected from street surfaces in the cities studied were composited in various ways to reflect a particular trend of interest. This applies to the data shown in Table G-13 and, therefore, should be treated accordingly when used in further analysis.

For samples collected from five cities there was little trend for the individual metals to be distributed in relation to particle size. An exception to that was lead. There seemed to be a distinct tendency for lead to be associated with fine particles (<246μ). The assumption has been made that the principal source of lead is antiknock gasoline additives, in which case the results are as expected from particulate automobile exhaust emissions.

Deicing Compounds - The salting of streets and highways to control ice and snow is beneficial in cutting down on highway deaths, injuries, and property damage. Because of the large quantities of salt used annually in salting streets, adverse environmental effects have been reported (28,29,30). Among the many are high chloride levels in snow melt runoff, sewage, and surface streams; high chloride levels and density stratification in lakes and impoundments; ground and surface water supply contamination; widespread damage of roadside soils, vegetation, and trees; high levels of chromium and ferrocyanide compounds used as road ice additives; and roadway damage and vehicle corrosion.

Extensive use of salt for deicing of streets and highways started in the early 1950's when the total annual usage in the U.S. was about 500,000 tons and has grown since then until the current usage is about 10 million tons/year. Salt usage for deicing in the State of Massachusetts has risen from about 25,000 tons/year in 1955 to about 225,000 tons/year in 1972. This represents an annual increase of about 13.6%. Since the miles of streets and highways also increased over that 18-year period the average annual application rate increased from 4.3 tons/lane-mile in 1955 to 23.7 tons/lane-mile in 1972, a rate of increase of about 10% per year. The application rate needed for deicing is very dependent on the climate. For example, Cincinnati, Ohio and Ottawa, Canada both have a population of about 500,000 with about 900 miles of streets but the salt usage in Cincinnati averages about 11,000 tons/year or 6 tons per lane-mile per year while the salt usage in Ottawa is 72,000 tons/year or 39 tons/lane-mile per year.

Cost Considerations - In recent years many have questioned the advisability of heavy use of salt for deicing, particularly, the use of the "bare pavement" policy. In a study by Abt Associates (28), it was estimated that the annual cost of adverse effects associated with the use of salt for deicing was 2.9 billion dollars. The greatest single damaging effect was attributed to corrosion of automotive vehicles at a cost of 2 billion dollars per year. Other damage estimates made in this report were 500 million dollars per year in damage to highway structures, 150 million dollars per year in damage to health and water supplies, 50 million dollars per year in damage to vegetation, and finally 10 million dollars per year in damage to utilities.

On the other hand, the Abt report did not attempt to quantify the beneficial effects of highway deicing through salt application. In order to establish an order of magnitude, this aspect of the question was addressed in a report (31) prepared by the Institute for Safety Analysis (TSIA) for the Salt Institute of Alexandria, Virginia. The total annual benefits associated with highway deicing was estimated at 18.4 billion dollars in the TSIA report. About 80% of the total was associated with lost wages and lost productive capacity caused by late arrival at work when no salt is used for deicing of streets and highways. TSIA estimated that about 42 million persons are employed in the snow belt at an average wage of $4.54/hour. Thus,

if each worker is delayed by two hours on each of twenty inclement weather days per year the total wages lost will be about 7.6 billion dollars per year. Workers engaged in manufacturing were estimated as 13.9 million within the snow belt. The value of lost productive capacity was estimated as $9 per hour. Thus, if each manufacturing worker is late for work by two hours on each of 20 inclement days per year the total loss in productive capacity is computed as 7 billion dollars annually. These two estimates account for 14.6 billion dollars annually or about 80% of the grand total for benefits.

Other categories of benefits estimated in the TSIA report were loss of wages because of absenteeism, loss of revenue earned in shipment of goods by truck, and increased use of automotive fuels. Wages lost as a result of absenteeism was estimated by assuming that 10 percent of the 42 million workers in the snow belt will be absent on each of 20 inclement days per year. Assuming an 8-hour day and $4.54 per hour in wages this benefit totals about 3 billion dollars annually. Potential losses to intercity truck revenue was based on an estimate of 93 million vehicle-miles traveled daily in the snow belt and an estimate that 70% of the vehicles-miles were load-carrying or revenue-producing. The revenue produced per vehicle-mile was estimated as $1.15 and a two-hour delay was assumed on each of 20 inclement days per year. Pick up and delivery trucks within the snow belt travel an estimated 189 million vehicle-miles per day or 13.5 million vehicle-miles per hour assuming a 14-hour work day. Of these vehicle-miles, it was estimated that about 48% were loaded and generating revenue at the rate of $2.20 per vehicle-miles. Using these assumptions the estimate for revenue lost due to a two-hour delay on each of 20 inclement days per year was computed as 600 million dollars annually.

The increased cost of automotive fuel was estimated from the additional fuel consumption known to be required for travel on snow- and ice-covered streets and highways. About 2,287 million vehicle-miles are traveled by all automotive vehicles in the snow belt daily. At an average gasoline mileage of 20.8 miles per gallon the total fuel consumption in the snow belt is about 110 million gallons/day. Estimating the cost of fuel at $0.60 per gallon the daily fuel cost is about 66 million dollars per

day. The increase in fuel consumption caused by hard-packed snow and ice cover on the streets was estimated at 15%. Thus, the daily cost for additional fuel was about 10 million dollars. Multiplying this by the estimated 20 inclement days per year gives a total annual additional fuel cost of 200 million dollars.

Although TSIA presented convincing evidence that time lost in responding to traffic accidents and other forms of medical emergencies can result in loss of life no attempt was made to place a monetary value on this aspect of the problem.

TSIA also reevaluated the categories of salt damage presented by the Abt Associates report. The TSIA estimate for total annual damage was one billion dollars as compred to the Abt Associates estimate of 2.9 billion dollars.

Although additional work might profitably be done to more precisely estimate the costs and benefits associated with the use of salt for deicing highways and streets it is clear from these two reports that neither of the two extremes of heavy salt use to implement the "bare pavement" policy or a prohibition on the use of salt are likely to represent the best solution.

As presented by Field et al., (29) aside from chemical melting, various methods for deicing are available or have been conceived which may become more prominent in the future especially when communities realize that a price must be paid to alleviate the pollutional effects of wintertime salting. Some of these methods are:

1. External and in-slab thermal melting systems.
2. Stationary (or pit) and mobile thermal "snow melters".
3. Substitute deicing compounds.
4. Compressed air or high-speed fluid streams in conjunction with snowplow blade or sweepers to loosen pavement bond and lift snow.
5. Snow adhesion reducing substances in pavement.
6. Pavement substances that store and release solar energy for melting.
7. Electromagnetic energy to shatter ice.

8. Road and drainage design modifications to enhance runoff, reduce wintertime accidents, and capture snowmelt for treatment or control.

9. Salt retrieval or treatment possibly enhanced by the addition of chelating agents.

10. Improved tire or vehicular design to reduce deicer requirements.

Although it is recognized that power, maintenance, and chemical costs for the above systems are high when compared to rock salt, municipalities, such as Burlington, Massachusetts have expressed a deep willingness to explore and demonstrate new methods regardless of cost. Burlington has recently suspended roadway salting practices when a study indicated that their well water chloride concentrations could exceed the recommended limit of 250 mg/l if salting was continued. It should also be pointed out that experience, operational data, and knowledge of environmental effects are lacking for the substitute chemical deicers.

G.3.6 Control of Particulate Fallout

The provisions of Section 208 of the Federal Water Pollution Control Act Amendments, as well as a variety of 208 planning guidance documents, mandate coordination between air quality maintenance planning and areawide waste treatment planning. Particulate material released into the atmosphere precipitates by gravity or through entrainment with precipitation and may contribute significantly to the dust-and-dirt cover on urban surfaces. This material is then available for incorporation as pollutant load in urban runoff.

Major sources of such materials are stacks and vents, construction and excavation projects, agricultural operations, and exposed vacant land areas. Automobile traffic and commercial air traffic are also sources of fine airborne particulates. Materials may be generated from activities entirely within the 208 area or through transport from other areas by prevailing winds.

Many such forms of fallout are largely inert and would contribute only to turbidity and suspended solids levels in runoff. Others, however, may be

reactive and possibly impose BOD, nutrient, and toxics loadings upon receiving waters. The extent to which each source contributes to the accumulation of specific pollutants on urban surfaces is a complex issue, and one that has not been adequately defined. Nonetheless, some coarse estimates can be made, particularly with regard to nontransportation related particulates, to provide a judgement regarding the potential impact of point source air quality control upon runoff.

In the 1950's and 1960's contaminants falling to the surface by gravity or as a result of being entrained in rainfall were routinely measured by means of dustfall jars. Dustfall jars were partially filled with water and placed in an elevated position, such as a rooftop, for a period of one month. The contents of the jars were then analyzed for mass of particulate material, composition, particle size distribution, etc. The use of dustfall jars has been discontinued in most communities in recent years in favor of the high-volume sampler. Johnson et al. (32) gives average values for dustfall in seven U.S. cities which range from a low of 15.5 tons/sq mi/mo in Tacoma, Washington, to a high of 63.8 tons/sq mi/mo in New York City. APWA (4) reported that the average dustfall in Chicago was 36.9 tons/sq mi/mo in 1966 and 41 tons/sq mi/mo in 1965. APWA also showed that the amount of dustfall depended on the month of the year, being least in August and maximum in February.

The amount of dust-and-dirt swept from streets as reported by APWA (4) was 79.2 lb/day/curb-mile. This estimate can be converted as follows to tons/sq mi/mo when the miles of street per acre is known and it is assumed that the area of the streets is about 28% of the total urban land area.

$$\text{tons/sq mi/mo} = 5431\ (\text{miles of street/acre})$$

The miles of street per acre in the 10-acre test area used by APWA (4) was 0.037. Therefore, the amount of dust-and-dirt was equivalent to 201 tons/sq mi/mo. Thus, it can be concluded that the measured dust-and-dirt originating from dustfall was approximately 30% of the total surface accumulation estimated from street sweeping experiments. Johnson (32) gave percentages ranging from 16-33% of the total dust-and-dirt which might originate from dustfall. These might well be over-estimates because there

is evidence that conversion from coal to oil and gas for heating and the imposition of air pollution regulations has reduced the amount of pollutants in urban air.

Thus, it may be seen that control of particulate air pollution will benefit pollution control. For illustrative purposes, the cost of particulate control will be compared with that of street cleaning.

One of the major sources of atmospheric particulates is coal-fired power generating stations. For this example a plant having the following characteristics will be considered: capacity - 1000 megowatts; conversion rate - 0.85 lb coal/kw-hr.; coal content - 15% ash; 85% of ash entrained in flue gas (no control); volume of gas - 4 million actual cubic feet per minute (acfm); electrostatic precipiator efficiency - 99%.

Using these assumed data the potential amount of flyash emitted from an uncontrolled stack can be estimated at approximately 900 million pounds per year. The cost of a 4-million acfm electrostatic precipitator installation is about $21 million (33). This amount amortized at 17% per year, typical of industrial depreciation rates, results in an annual cost of $3,570,000. Operating and maintenance cost will be about $178,000 and the cost of power at three cents per kw-hr is about $850,000 per year. The total cost of removing over 99% of the particulate is about $4.6 million dollars/year. Thus, the cost of removing particulate material at the source is about a half cent per pound.

On the other hand, the cost of mechanical street sweeping to remove dust-and-dirt from street surfaces is more expensive. Using the APWA accumulation rate for Chicago (79.2 lb/day/curb-mile), a seven day sweeping frequency, 50% sweeper efficiency, and the average sweeping cost developed in Section G.3.1 ($10.40/curb-mile), the cost of removing dust-and-dirt may be estimated at roughly four cents per pound of dust-and-dirt removed.

Thus, it appears that removing the particulate material at the source is less expensive by a factor of nearly 8. In smaller sized power plants the cost will be somewhat higher per pound of particulate removed but not likely to equal the cost of removing dust-and-dirt from the street by sweeping. It should also be remembered that particulate control would effect all urban land area, including streets. However, on a BOD basis it is difficult to estimate the impact of particulate source control. For the example above

the effect upon potential BOD loadings from urban runoff would be negligible. For other industrial or municipal sources which could contain oxygen demanding materials the impact could be greater.

G.4 Collection Systems Control Alternatives

G.4.1 Introduction

The goal of management practices applied to collection systems is either hydraulic control to minimize the volume of storm runoff and municipal sewage which overflow into the receiving stream without treatment, or loading controls to minimize the pollutants which are contained in urban stormwater runoff and combined sewer overflows. During combined sewer flows in excess of treatment plant capacities are a storm event diverted around the treatment plant and are generally discharged directly into a receiving stream without treatment. Since the overflowed excess is comprised of untreated sanitary wastes and a wide variety of environmentally disruptive substances, a potential public health hazard and an adverse stream quality impact results.

It is the purpose of this section of this appendix to review the quantification of combined sewer overflow events and volumes, and to review the management alternatives for controlling the volume and/or pollutant loadings attributable to combined sewer overflows.

G.4.2 Volume Control

G.4.2.1 Review of Available Analytical Techniques

A number of reports have attempted to estimate the annual number of hours during which combined sewer overflows are likely to occur as a function of interceptor capacity expressed as a multiple of DWF. One of the first was by McKee (34) who estimated the number of times overflow occurred and the fraction of sanitary sewage it contained based on the intensity distribution of the hourly rainfall.

Assuming the population density and the rate of inflow both increase as the runoff coefficient increases, the calculated that the rainfall intensity producing a runoff flow equal to dry weather flow approximates 0.01 inch/hour for all communities. He also estimated that the first 0.03 inches of each rainfall event would be used in wetting the land surface and would result

in no runoff. While this correction made little difference in the rainfall distribution pattern, rainfall time was essentially reduced from 6.64% to 5.56%. Implicit in this analysis was the assumption that the runoff coefficient was the same for all intensities. The result of McKee's analysis is shown in Figure G-7 (curve A) as the number of hours per year combined sewer overflows will occur as a function of interceptor capacity expressed as multiples of the dry weather flow rate.

The results of a study of combined sewer overflows in Detroit were presented by Palmer (35). His analysis was for a part of Detroit having a population density of 40 persons/acre and an estimated dry weather flow of 162 gal/capita/day. Following McKee's lead, Palmer estimated the equivalent dry weather flow at 0.01 inch/hour, and also assumed that rainfall equal to or less than 0.03 inch/hour would produce no runoff. The number of hours per year in which the rainfall exceeded 0.03 inch per hour was 263 hours, or 3% of the time. Palmer's estimate of annual hours of combined sewer overflow as a function of interceptor capacity is shown as curve B in Figure G-7.

St. Louis was the site of a similar analysis of combined sewer overflows made by Shifrin and Horner (36). The area studied had a population density of 27 persons/acre and the estimated dry weather flow of 166 gal/capita/day. They estimated the rainfall equivalent of dry weather flow at 0.007 inch/hour and assumed that 0.4 inch of depth is required to wet the land surface. In this analysis only a very limited range of interceptor capacity was considered. The results are shown as curve D in Figure G-7.

Johnson (37) made a study of the number and duration of overflow events at eight overflow points in the Washington, D.C. combined sewer system. His analysis was similar to those of McKee and Palmer. The results, shown as curve C in Figure G-7, demonstrated that the measured annual hours of overflow exceeded the calculated estimates for six out of the eight overflow sites studied.

Benjes et al (38) made a study of expected combined sewer overflow hours/year in Kansas City. Benjes estimated the dry weather sanitary flow as equivalent to 0.0035 inch/hour, and assumed that 0.04 inch of rain was required to wet the land surface. The results of this study are shown as curve E in Figure G-7.

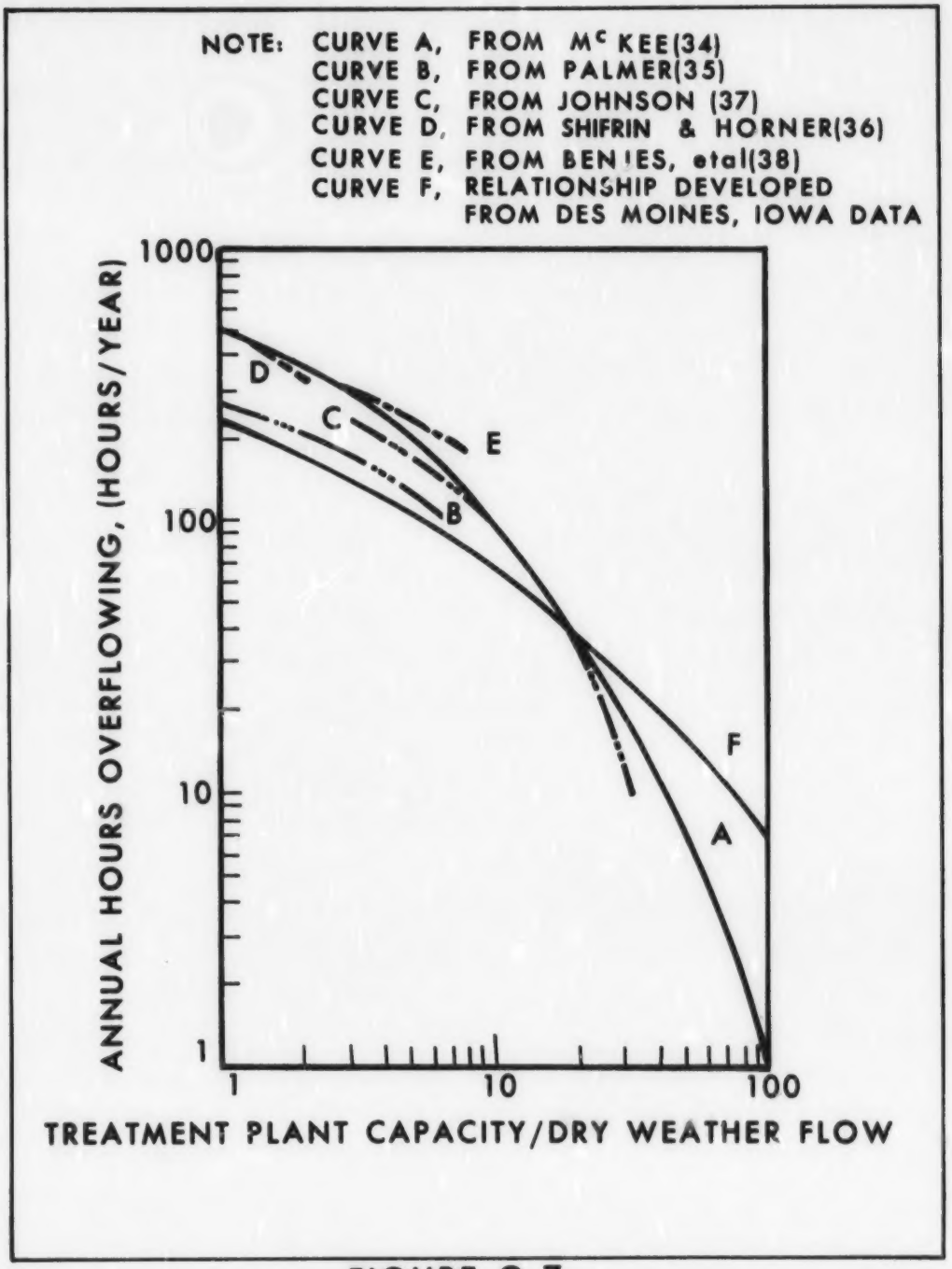

FIGURE G-7
ESTIMATED ANNUAL HOURS OF OVERFLOW VERSUS TREATMENT PLANT HYDRAULIC CAPACITY

Each of the foregoing studies of combined sewer overflow frequency recognized that a threshold rainfall exists, below which no measurable runoff occurs. Palmer believed that the intensity must exceed 0.03 inch/hour before runoff will occur and the other studies all eliminated some quantity (0.02-0.04 inches) from the initial hours of each event. Also, all five studies incorporated an estimated runoff coefficient into the calculation of the amount of rainfall which is equivalent to dry weather flow. The same runoff coefficient was then implicitly assumed for all intensities above the threshold value. All five investigators concluded that the capacity of the interceptors must be very large in order to effect a significant reduction in the annual hours of combined sewer overflows. As a result of the study made by Johnson, a ratio of 30 between interceptor design flow and dry weather flow was adopted for use in portions of the Washington, D.C. area. According to Johnson at a WWF:DWF ratio of 3 the combined sewers would overflow 240 hours per year. When the WWF:DWF ratio was increased to 30 the overflow hours per year would be reduced to 13 hours per year. This represents a reduction in the time of overflow of about 95%. The principal weakness of the analyses described above is the assumption that the runoff coefficient is independent of the rainfall intensity. In order to avoid having to make this assumption, Davis and Borchardt (39) made measurements of the runoff coefficient in Des Moines based on the rational method. Measurements were made for two catchments: catchment 0-11 having a population density of 10.7 persons/acre and catchment S-3 having a population density of 5.3 persons/acre. Calculated runoff coefficients for each catchment as a function of rainfall intensity are shown in Figure G-8. A regression line for catchment 0-11 data has been plotted in Figure G-8, and the equation relating the runoff coefficient to rainfall intensity is shown below:

$$C = 0.3836 + \ln(I)/9.48248 \qquad \text{(G-13)}$$

I = rainfall intensity, in/hr

I_r = runoff, in/hr

$C = I_r/I$

Extrapolating the regression line in Figure G-8 it is seen that the rainfall intensity which produces no runoff would be about 0.026 inch/hour. This

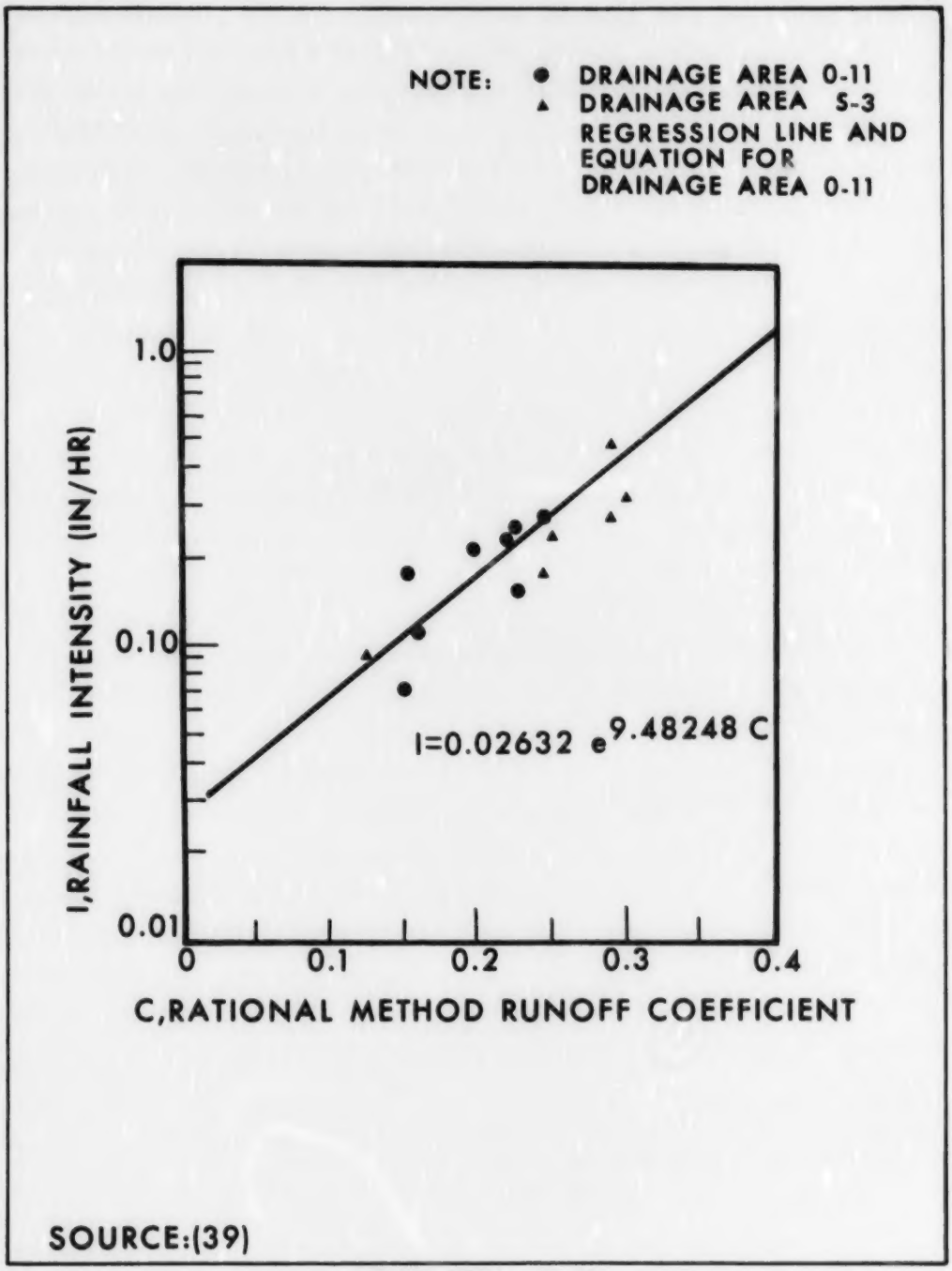

FIGURE G-8
RATIONAL METHOD RUNOFF COEFFICIENT
VERSUS RAINFALL INTENSITY

figure agrees well with the estimates of 0.03-0.04 inch per hour which had been assumed by previous investigators.

The relationship between runoff coefficient and rainfall intensity is known to depend on percent imperviousness which, in turn, is believed to be related to population density. In their Des Moines study, Davis and Borchardt (39) found that for an urban area with a population density of 10.7 persons/acre the rate of runoff could be related to rainfall intensity as follows:

$$CFS/Ac = I(0.380 + \ln(I)/9.526) \qquad \text{(G-14)}$$

I = rainfall intensity, in/hr

Using the relationships of Chapter 3, the value for C_v at a population density of 10.7 persons/acre is about 0.35 as compared to a value of 0.38 at a population density of 13.1 persons/acre. Thus, for a rough estimate, the runoff coefficient shown in Figure G-8 for catchment 0-11 would be increased by 10% to find the expected runoff coefficient for a population density of 13.1 persons/acre.

To convert a distribution of hourly rainfall intensities to a distribution of runoff rates, Equation (G-13) can be used. Using the data of Davis and Borchardt (39), a distribution of hourly equivalent runoff is plotted in Figure G-9.

However, runoff rates are more meaningful when expressed as multiples of the dry weather flow of municipal sewage. If the production of municipal sewage is estimated as 100 gal/capita/day, the flow will be 0.00131 mgd/acre at a population density of 13.1 which is equivalent to a runoff rate of 0.00201 inches/hour.

If the rainfall intensity is less than 0.026 inch/hour no runoff will occur. The distribution of rainfall intensities shown in Figure G-9 indicates that about 46% of the rainfall hours have intensities greater than 0.026 inch/hour. Therefore, since the total rainfall hours was 489 hours/year in Des Moines over the 10-year period between 1950 and 1960, the combined sewer would overflow 225 hours/year if the interceptor capacity is just equivalent to the dry weather flow. If the runoff rate is equal to the dry weather flow, the rainfall intensity will be 0.0403 inch/hour and this intensity of rainfall

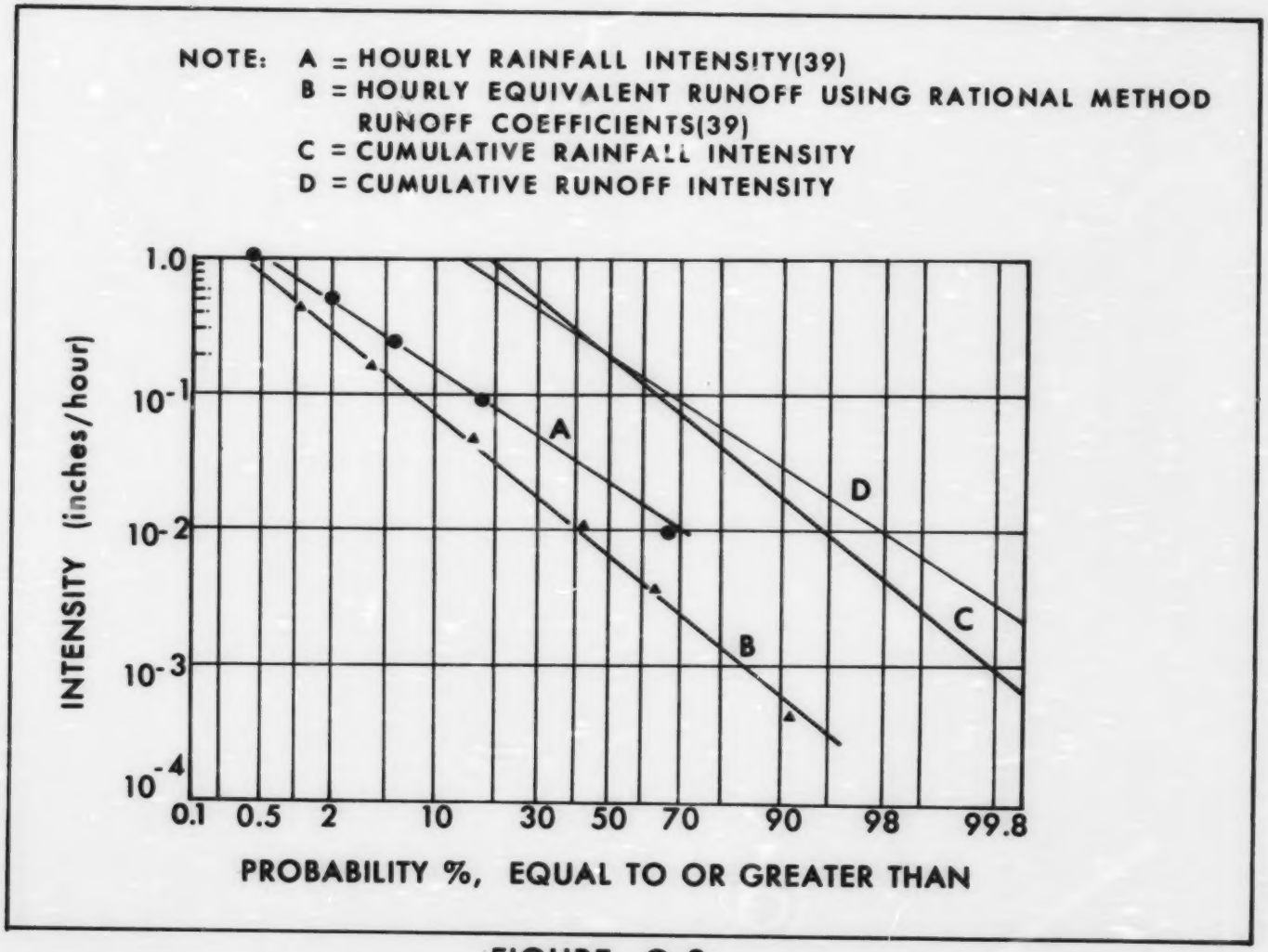

FIGURE G-9
PROBABILITY DISTRIBUTION OF RAINFALL AND RUNOFF INTENSITIES

will be exceeded 196 hours per year. Using this reasoning, the relationship between WWF:DWF ratio and annual hours of overflowing has been developed for the Des Moins data, and is shown as curve F in Figure G-7. It can be seen that the potential for limiting the number of hours during which overflowing occurs is significant. If the capacity of the treatment plant is 3.5 times the dry weather flow the total annual overflow will be reduced from 225 to 125 hours, which is a reduction of 44%. A 90% reduction in the number of hours of overflow could be achieved but only if the plant capacity is 35 times the dry weather flow.

It is generally accepted that a large fraction of the total overflow volume is contributed by a few high-intensity storms. As a result, the potential for making a major reduction in the total amount of overflow by increasing the capacity of the plant and sewerage system is considerably reduced. To quantify this facet of the situation the first moment of the distribution of runoff rates must be found.

Since both the distribution of rainfall intensities and the distribution of runoff rates appear to be log-normally distributed the first moment of the distribution functions can be computed as given in Smith (8). The mean rainfall intensity for Des Moines was computed as 0.0672 inch/hour and this value when multiplied by the total number of rainfall hours (489) gives a total accumulation of 32.86 inches per year. Similarly, the mean value for runoff is 0.03546 inch/hour and this value times 225 hours/year of runoff gives an accumulated runoff amount of 7.97 inches per year. Thus, the average runoff coefficient for Des Moines at a population density of 13.1 is 7.97/32.86 or 0.243.

By using the first moment of the distribution of runoff rates, the fraction of the total amount of runoff (7.97 inch/year) which will escape when the capacity of the plant is some multiple of the dry weather flow can be found. The results of this calculation are shown by the zero percent curve in Figure G-10. It can be seen that to reduce the runoff volume which overflows by 50% the capacity of the treatment plant must be 100 times the dry weather flow rate.

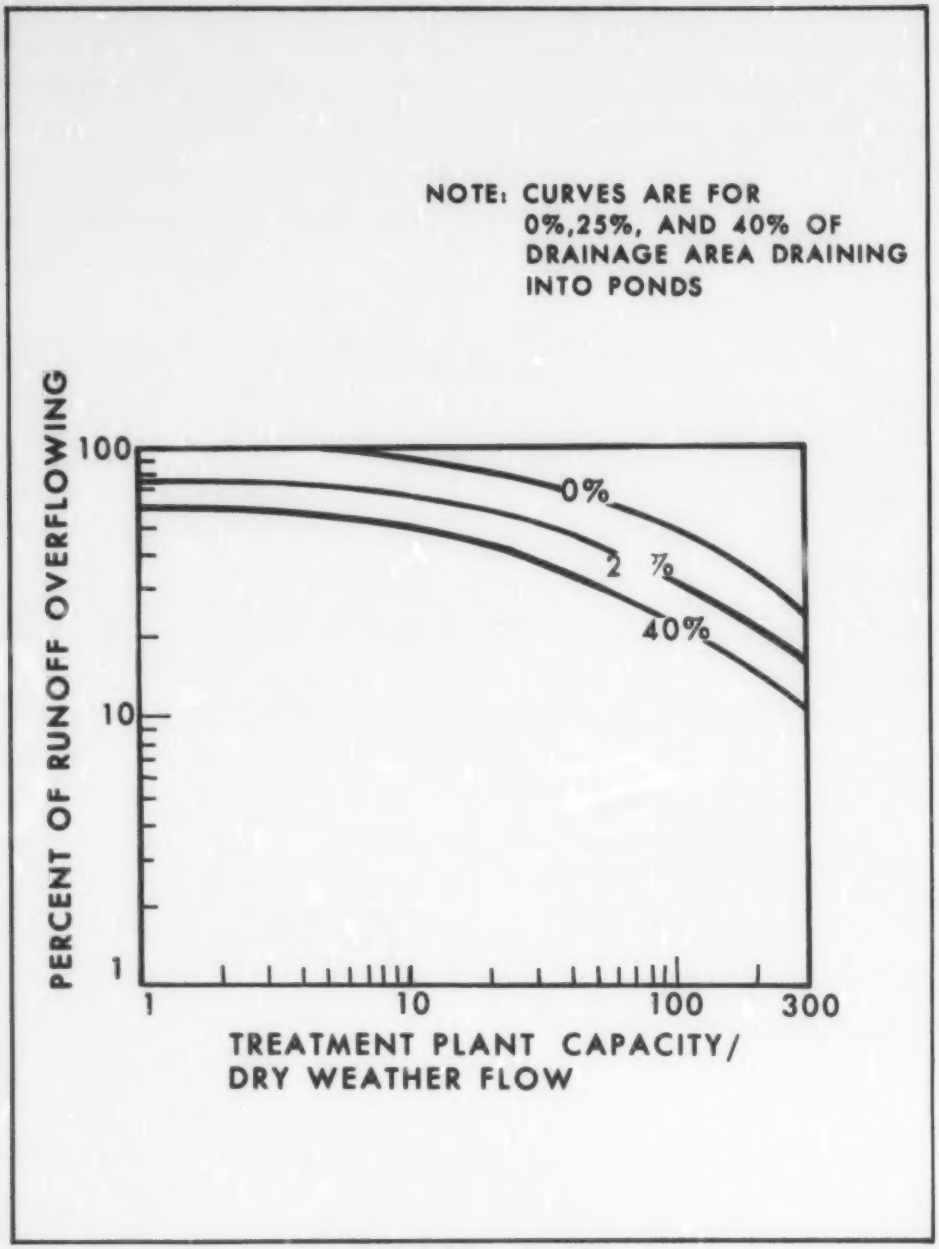

FIGURE G-10
EFFECT OF UPSTREAM STORAGE ON PERCENTAGE OF TOTAL RUNOFF VOLUME OVERFLOWING VERSUS TREATMENT PLANT HYDRAULIC CAPACITY

If the concentration of pollutants in the runoff were the same in each volume of runoff this estimate of the fraction of runoff escaping would lead to a pessimistic view of the potential for limiting pollution by increasing the capacity of the plant and sewerage system. However, since there is some evidence that a larger fraction of the pollutants are present in runoff from smaller storms, and especially in the first flush, the analysis based on number of overflow hours may have more validity. If the concentration of BOD is assumed to be the same for all runoff the concentration can be computed as follows:

$$\text{BOD, mg/l} = 4.422\ (\text{BOD loading, lb BOD/acre-yr})/(\text{annual runoff, in/yr}) \qquad \text{(G-15)}$$

Thus it can be seen that if the annual runoff is 7.97 in/yr and the storm sewer loading is 30 lb BOD/acre-yr the average BOD concentration will be 16.1 mg/l. Similarly, if the combined sewer loading is 100 lb BOD/acre-yr the average BOD concentration will be 55.5 mg/l.

G.4.2.2 Storage in the Sewerage System

The municipality of Metropolitan Seattle has installed and demonstrated (40) a computer augmented treatment and disposal system (CATAD) which monitors and controls storage of runoff in a combined sewer system serving an area of 13,120 acres. It was shown that storage of storm runoff in trunks and interceptors can reduce the volume of runoff escaping by about 74% when the regulator gates are manually controlled from a central control panel, and by about 90% when the gates are controlled automatically by computer algorithms.

Although performance measurements made on the CATAD system were very scattered there is little question that, in sufficiently large communities, storage of runoff in the sewerage system is a viable strategy for reducing or eliminating the volume of runoff which escapes into the receiving stream. For example, by means of the following simple analysis the storage volume available in the interceptors can be roughly estimated. If the interceptors are designed to transmit K times the dry weather flow with a Manning roughness coefficient of 0.013, the required interceptor diameter can be found from the following relationship.

$$D = 0.308 \, (K \, DWF/S^{1/2})^{0.375} \qquad \text{(G-16)}$$

D = interceptor diameter, ft

K = multiple of DWF

DWF = dry weather flow, mgd

S = interceptor slope, ft/ft

In the 1967 APWA survey (7) of combined sewer problems it was found that of the 109,000 miles of sewer installed about 7,600 miles or 7% were interceptors. Thus, if the length of interceptor is taken as 7% of the total sewer length shown in Figure G-2, and the interceptor diameter is found from Equation (G-16), the volume of the interceptor can be calculated as follows:

$$V = 0.002171 \, D^2 \, L \qquad \text{(G-17)}$$

V = interceptor volume, mg

L = interceptor length, miles

If dry weather flow is taken as 100 gpd/capita, the interceptor is sized to transmit four times the dry weather flow, and the slope of the interceptor is assumed to be 0.0003 ft/ft, the diameter of the interceptor will vary from about 2 ft at a population of 10,000 to a diameter of 7.5 ft at a population of about 220,000. Up to a population of 45,000 the slope must be increased to provide the minimum velocity of 2 ft/sec necessary to provide adequate scouring. Since 7.5 ft diameter is near the upper limit of current practice it has been assumed that for populations above 220,000 multiple 7.5 ft diameter interceptors will be provided.

Based on the assumptions itemized above, the interceptor volume can be expressed by the following expressions as a function of the drainage area in acres.

$$V = 0.078 \, (Acres/1000)^{2.3} \qquad \text{(G-18)}$$

$$V = 0.0217 \, (Acres/1000)^{2.76} \qquad \text{(G-19)}$$

Equation (G-18) applies from 10,000 to 17,500 acres or from 100,000 to 220,000 population and Equation (G-19) applies from 17,500 to 50,000 acres or for a population greater than one million.

The CATAD system served an area of 13,120 acres and had a design storage of 29.8 mg, however, it was found that the actual storage was only 17.83 mg or about 60% of the design storage. Substituting an area of 13,120 acres into Equation (G-18) gives an estimate of 29.1 mg which shows that the estimates made agree reasonably well with the CATAD system.

The important conclusion to be drawn from Equations (G-18) and (G-19) is that the available interceptor storage volume increases very rapidly with the area drained. The volumetric runoff coefficient measured in the CATAD testing program was 0.152. Using this value for C_v and the ratio of design storage to actual storage of 0.6, Equations (G-18) and (G-19) can be used to express the volume of rain (inches) which can be stored in the sewerage system for any size drainage area.

$$\text{Stored rainfall, inches} = 0.01134\ (\text{Acres}/1000)^{1.3} \qquad \text{(G-20)}$$

$$\text{Stored rainfall, inches} = 0.003155\ (\text{Acres}/1000)^{1.76} \qquad \text{(G-21)}$$

Equation (G-20) is used with Equation (G-18), and Equation (G-21) is used with Equation (G-19). Since the area of the metropolitan area is a function of the population the inches of rainfall which might be stored can also be expressed as a function of the population as follows.

$$\text{Stored rainfall, inches} = 3537 \times 10^{-6}\ (\text{POP}/1000)^{0.905} \qquad \text{(G-22)}$$

$$\text{Stored rainfall, inches} = 637.8 \times 10^{-6}\ (\text{POP}/1000)^{1.225} \qquad \text{(G-23)}$$

From Equation (G-20) it can be seen that for the Metro Seattle case where the drainage area was 13,120 acres, a maximum of 0.322 inches of rain can be stored in the collection system. Rainfall records for the Seattle area showed that rainfall exceeded 0.1 in/day for 88 days/year, 0.25 in/day for 46.6 days/year, and 0.5 in/day for 17.6 days/year. These three points appear to fit an exponential distribution expressed as follows:

$$F(I) = 1 - e^{-4I} \qquad \text{(G-24)}$$

I = rainfall intensity, in/day

$F(I)$ = fraction of rain days with intensities less then I

The total number of days/year in which some rain fell was 130 days. Therefore, it can be seen that rain intensity will be less than 0.322 in/day for

72.4% of the 130 days/year or 94 days/year. This is clearly a significant reduction in the number of days overflowing occurs.

It is also important to examine the volume of runoff which is contained. The first derivative of Equation (G-24) is the probability density function. Multiplying the probability density function by I, and integrating from zero to infinity gives a total annual rainfall of 32.5 inches/year. The amount of rain falling in days with intensities less then I can be expressed as follows.

$$C = 32.5(1 - e^{-4I}(1+4I)) \qquad \text{(G-25)}$$

C = cumulative rainfall, in/yr

From Equation (G-25) it can be seen that the total amount of rainfall contained during days when the intensity was less than 0.322 in/day is 11.98 in/year or about 37% of the total annual amount. However, during days when the intensity exceeds 0.322 in/day the first 0.322 in/day can also be stored.

Since it has already been shown that 94 days/year had intensities less than 0.322 in/day, it follows that 130 minus 94 or 36 days/year will have intensities greater than 0.322 in/day. Thus, of 0.322 inches stored during each of the 36 days, an additional 11.59 inches of rain will be contained. Adding 11.59 to 11.98 gives a total of 23.6 in/year contained. Therefore, a total of about 73% of the runoff can be contained. This estimate agrees well with the findings of the CATAD system using manual control of the gates. This analysis, however, implicitly assumed that the interval for storing and releasing the runoff was one day. If the adjustment period is less than one day greater fractions might be contained.

It can be seen from this simplistic analysis that storage in the collection system offers a significant potential for reducing the amount of overflow. In addition to overflow volume the potential for reducing pollution loading is also impressive because of the potential for containing small storms and the first flush of larger storms where a large fraction of the pollution is believed to originate.

The total construction cost for the CATAD system was about 3.9 million dollars in mid-1968 which would correspond to about 8.5 million current dollars. This

corresponds to about $650/acre drained. Amortizing at 6% over 20 years gives $56.67/acre/year. Operating cost was estimated at $5/acre in 1974 or about $6/acre in current dollars. If 75% of the pollutional load or about 75 lb BOD/acre-year is contained the cost in terms of pollution control is about $0.84 per pound of BOD removed.

G.4.2.3 Use of Combined Sewer Regulators

Combined sewer regulators are designed to intercept all dry weather flows and automatically bypass wet weather flows which are greater than the interceptor and/or treatment plant capacity. Originally, a low dam or weir was constructed across the combined sewer downstream from a vertical or horizontal orifice. Flows dropping through the orifice were collected by the interceptor and conveyed to the treatment plant. Although more sophisticated mechanical regulators were developed to improve control over the diverted volumes, no specific consideration was given to quality control. More recently, several regulators have been developed which are capable of providing both quality and volume control through induced hydraulic flow patterns that tend to separate and concentrate the solids from the main stream (41,42,43).

Conventionally designed regulators can be subdivided into three major groups: (1) static, (2) semiautomatic dynamic, and (3) automatic dynamic. The grouping reflects the general trend toward the increasing degree of control and sophistication and, of course, the capital and operation and maintenance costs. Conventional regulator design, use, advantages, and disadvantages are well covered in the literature (41,44).

Recent emphasis has resulted in the development of several new and innovative regulators both in the United States and in Europe (45). Those showing the greatest promise are undergoing prototype testing. Regulators included in this group are fluidic devices, swirl concentrators, broad-crested inflatable fabric dams, and automatic slide gates and tide gates. Improved regulators developed in England include the vortex regulator, high side-spill weir, stilling pond regulator, and the spiral flow regulator. The choice of a regulator must be based on several factors including: (1) quantity control, (2) quality control, (3) economics, (4) reliability, (5) ease of maintenance, and (6) the desired mode of operation (automatic or semiautomatic).

G.4.2.4 Use of Swirl Concentrators as Combined Sewer Regulators

The swirl regulator/concentrator has shown outstanding potential for providing both quality and quantity control, and is believed to be practical for installation at overflow points along an interceptor. In the following illustrative example the average number of combined sewer overflow points per 1000 acres of catchment and per 1000 population was given in the 1967 APWA survey (7) of combined sewer problems. These are shown in Figures (G-11) and (G-12). Construction cost for swirl concentrators was estimated by Benjes (46) and the cost is expressed by the following relationship in December 1976 dollars.

$$\text{Construction cost, dollars} = 772.72\ A^{0.7727} \qquad \text{(G-26)}$$

A = swirl concentrator surface area, sq. ft.

The following sizing relationship was developed by APWA (45) for 90% removal of suspended solids.

$$A = 30(CFS)^{0.7588} \qquad \text{(G-27)}$$

CFS = peak flow rate, cfs

Assuming that the total overflow rate (cfs/acre) is equally divided among the various overflow points, the following relationship for construction cost in terms of dollars/acre can be derived by substituting Equation (G-27) into Equation (G-26).

$$\text{Construction cost, \$/acre} = 10{,}700(CFS/Ac)^{0.586}(N/Ac)^{0.414} \qquad \text{(G-28)}$$

N/Ac = number of overflow points per acre

CFS/Ac = overflow rate, cfs/acre

Operating and maintenance cost given by Benjes (46) can be expressed as follows in terms of annual man-hours. No power or chemicals are required. The manpower consists of one inspection of each swirl concentrator every two weeks (2 hr/inspection) and washing of the concentrator after every overflow event. It is assumed that 30 overflows will occur each year.

$$\text{Annual man-hours per concentrator} = 52 + 78.16\ A^{0.306} \qquad \text{(G-29)}$$

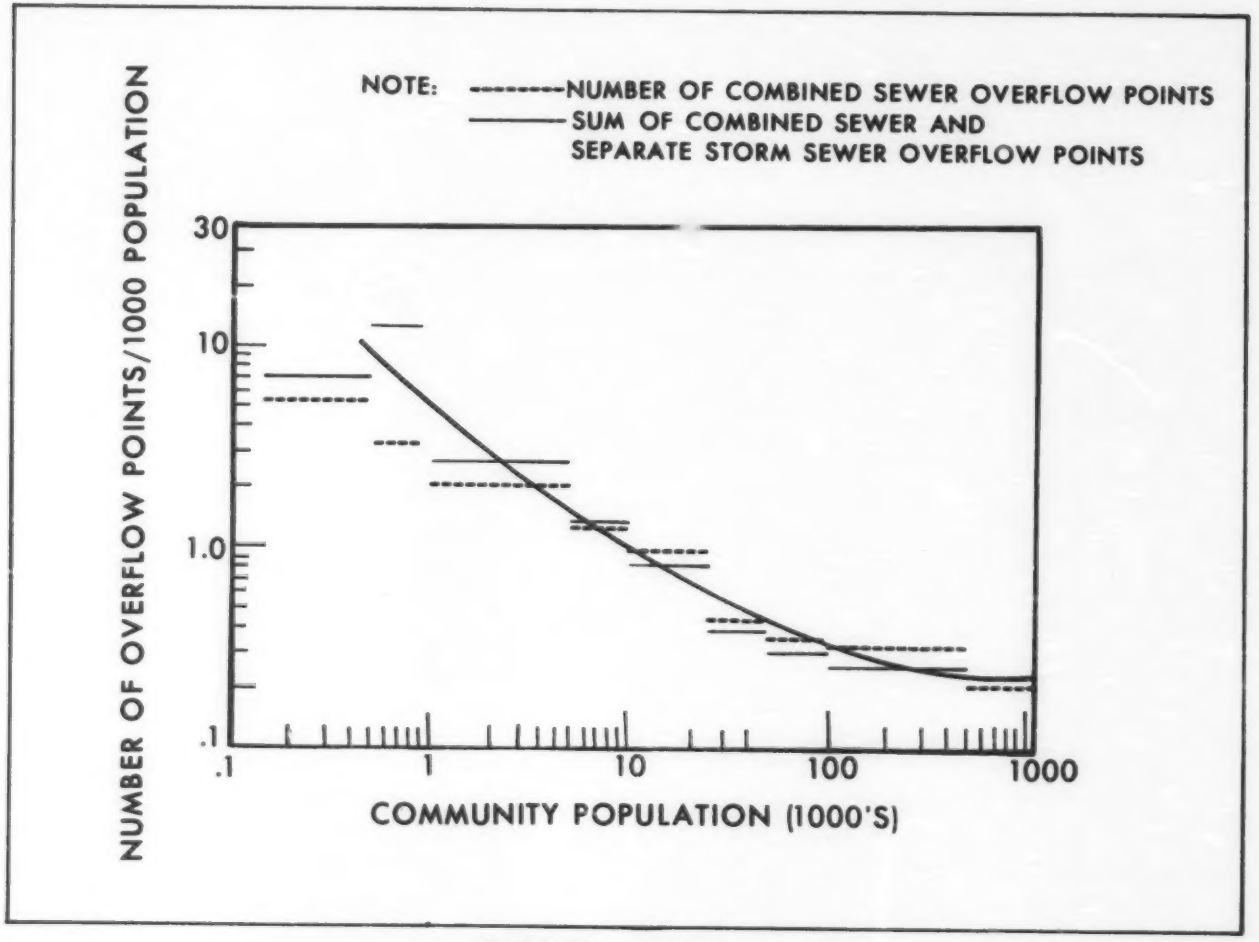

FIGURE G-11
NUMBER OF SEWER OVERFLOW POINTS PER 1000 POPULATION VERSUS COMMUNITY POPULATION

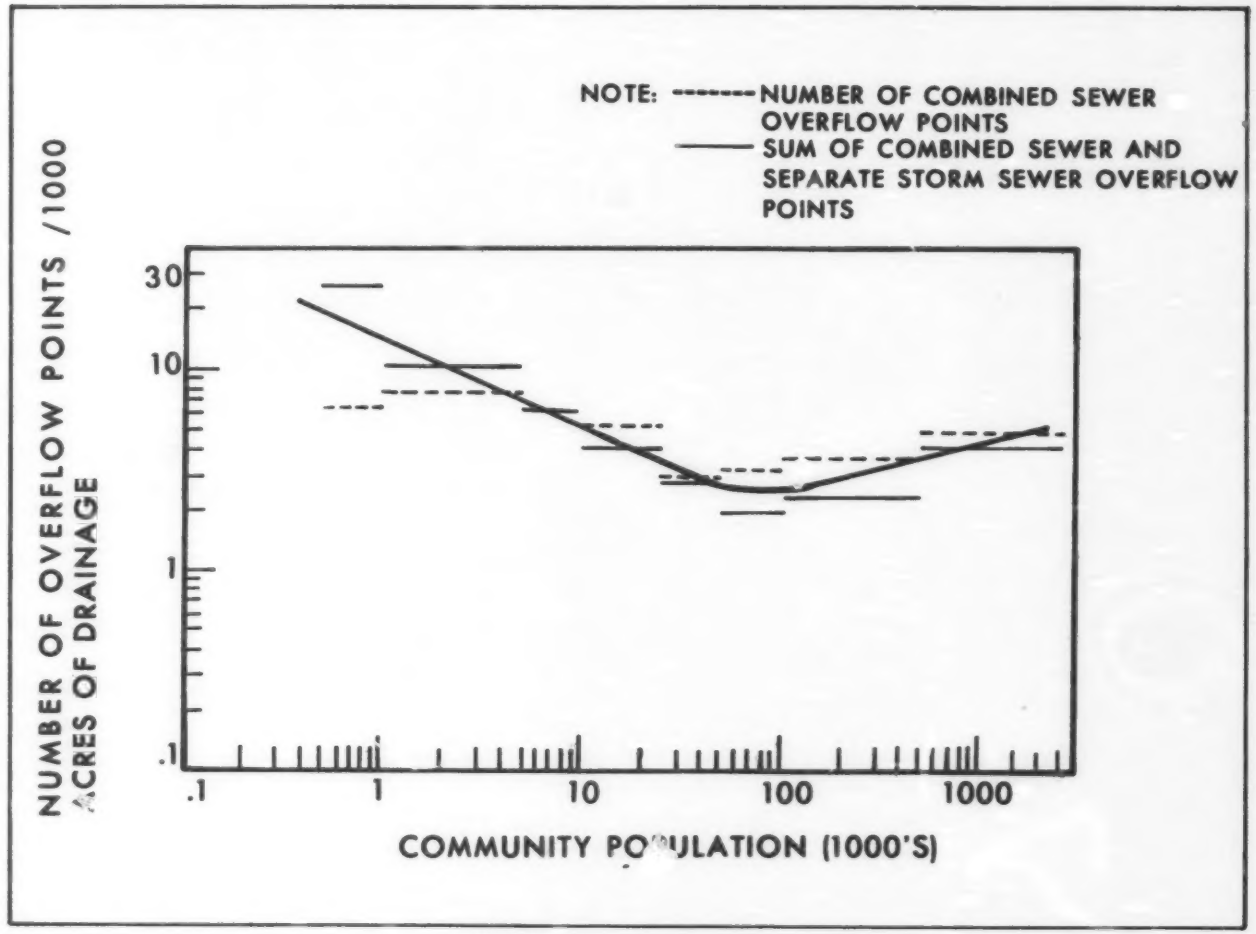

FIGURE G-12
NUMBER OF OVERFLOW POINTS PER 1000 ACRES OF DRAINAGE AREA VERSUS COMMUNITY POPULATION

Combining Equations (G-28) and (G-29) and assuming a manpower cost of $10/hour the following relationship is derived for operating and maintenance cost expressed as dollars/acre-year.

$$\text{O\&M cost, \$/acre-yr} = \$520\ (\text{N/Ac}) + \$2213\ (\text{N/Ac})^{0.768}\ (\text{CFS/Ac})^{0.232} \qquad \text{(G-30)}$$

It can be seen that both the construction and the operating and maintenance costs depend on the number of overflow points per acre (N/Ac) and the runoff rate in CFS per acre.

If the production of municipal sewerage is assumed to be 100 gal/day/capita the rate of flow for municipal sewerage can be expressed as 0.000155 CFS/acre times the population density. If the population density is 10.7 and the capacity of the interceptor is assumed to be 3.5 times the rate for municipal sewage the interceptor capacity will be 0.0058 CFS/acre. Rates of flow exceeding this amount will be assumed to overflow.

From Figure (G-9) it can be seen that in Des Moines (39), the intensity of rainfall will exceed one inch/hour in only about 0.5% of the rainfall hours or 2.5 hours/year. Using one inch/hour as the design point for the sizing of swirl concentrators, and using Equation (G-14), it is calculated that the runoff rate at 1 inch/hour will be 0.380 CFS/acre. By subtracting the capacity of the interceptor (0.0058 CFS/acre) from the runoff rate the overflow rate is calculated to be 0.074 CFS/acre. In Figure G-12 it is seen that the number of overflow points per acre of urban land varies with the population. A representative value is about 0.0035 overflow points per acre.

An average construction cost per acre for swirl concentrators can now be found by substituting a value of 0.374 CFS/acre and a value of 0.0035 for number of overflow points per acre into Equation (G-28). For the 50,000 population community the construction cost is $586/acre, but in very small communities the cost could be as much as $1000/acre. Taking the useful life of the swirl concentrators as 20 years, the interest rate as 6%, and the ratio of capital to construction cost as 1.35 the amortization cost will be about $70/acre-year but this amount might be as high as $120/acre-year for small communities. Operating and maintenance cost can be estimated by substituting values for N/Ac and CFS/Ac into Equation (G-30). If 0.374 CFS/ac

and 0.0035 overflow points per acre are used, the annual operating and maintenance cost will be about $25/acre-year. This could be as high as $78/acre-year for very small communities where the value for N/Ac is 0.015. Thus, the total cost of owning and operating swirl concentrators in most communities is likely to be about $95/acre-year, but could be as high as $200/acre-year for very small communities.

The swirl concentrator is capable of removing about 50% of the BOD from the overflow. Thus, if the annual load from combined sewers is 196 lb BOD/acre-year, 48 lb BOD/acre-year might be removed by the swirl concentrators. Dividing the previously calculated $95/acre-year by 48 lb BOD/acre-year gives an estimate of $1.98 per pound of BOD removed when swirl concentrators are installed at all overflow points of a combined sewerage system. This is two-thirds the cost of $2.94/lb BOD removed which is estimated later in Section G.4.2.6 for installing separate sewers in undeveloped land.

G.4.2.5 Reduction in Infiltration/Inflow (I/I)

A serious problem results from both excessive infiltration and high inflow rates into sewer systems: both limit the capacity of the sewerage system and the treatment plant to handle runoff resulting in increased amounts of overflows and treatment plant bypasses. Infiltration usually occurs from groundwater sources seeping into sewer pipes from leaky joints, crushed or collapsed pipe segments, leaky lateral connections, or other pipe failures. Inflow usually occurs from surface runoff, from roof leaders, cellar and yard drains, foundation drains, commercial and industrial "clean water" discharges, drains from springs and swampy areas, depressed manhole covers, cross-connections, and the like. The subject of I/I control strategies and costs has been thoroughly reported by Lager and Smith (2). The information presented in this section has been adopted from their report.

G.4.2.5.1 Inflow Control

Correction of inflow conditions is dependent on regulatory action on the part of city officials, rather than on public construction measures. If elimination of existing inflows is deemed necessary because of adverse effects of these flows on sewer systems, puming stations, treatment plants,

or combined sewer regulator-overflow installations, new or more restrictive sewer-use regulations may have to be invoked.

The effects of inflows into sewers can be greatly reduced by a variety of methods. Many authorities advocate the discharge of roof water into street gutter areas--or onto on-lot areas in the hope that it will percolate into the soil (47). Discharging roof or areaway drainage onto the land or into street gutters reduces the immediate impact on the sewer system be allowing reduction of the volume and attenuation of the flow. The use of pervious drainage swales and surface storage basins within urban areas allows the stormwater to percolate into the ground.

Depressed manholes (those with vented covers in street areas where runoff can pond over the cover) can be repaired or the covers replaced with unvented covers.

The elimination of inflow sources is generally found to be cost effective. Some of the most common sources of inflow are summarized in Table G-14. Estimates for the flow contribution by each source and the cost of eliminating that source are summarized in the following table.

TABLE G-14

COST ESTIMATES FOR INFLOW ELIMINATION

Source elimination	Flow rate, in gallons per minute	Rehabilitation cost in 1974 dollars, $
Leakage around manhole covers	10-20	50-75
Holes in manhole covers	50-100	100-125
Foundation drain disconnection	10	300-1,200
Roof leaders disconnection	10	50-75
Cross-connection plugging	250-450	100-500
Catch basin	300	3,000-5,000
Ditch or storm sewer, infiltration sanitary sewer (per manhole reach)	60-80	500-2,500
Area drain disconnection	50-200	50-350

G.4.2.5.2 Control of Infiltration

The average rate of infiltration represents a minor fraction of the hydraulic capacity but the peak infiltration rate can be several times the dry weather flow. For example, the most commonly used allowance standard for infiltration is 500 gallons per inch of pipe diameter per mile per day. Santry (48) itemized the length and diameter of sewer pipe in three communities and the average pipe diameter ranged from 9.82 inches at a total sewer length of 2822 miles to a low of 6.51 inches at a length of 6.3 miles. The three data points are well represented by the following relationship.

$$D_a = 5.75\ L^{0.67348} \qquad \text{(G-31)}$$

D_a = average pipe diameter, inches

L = total length of sewer, miles

At a population of 50,000 the length of sewer will be about 128 miles, the average pipe diameter will be about 8 inches, and the population density will be about 8 persons/acre. Assuming the dry weather flow as 100 gal/capita/day the flow of municipal sewage will be 800 gal/acre/day. The infiltration rate allowed is 4000 gal/mile/day. Since the miles of sewer per acre is about 0.021, the infiltration rate allowed is 84 gal/acre/day or about 10.5% of the dry weather flow. In terms of dry weather flow the infiltration allowances ranged from 10% of dry weather flow to as much as four times dry weather flow. It can be seen from Figure G-7 that if the infiltration equals twice dry weather flow, the capacity of the treatment plant, in multiples of dry weather flow, must be reduced by two. For example, if the capacity of the treatment plant is four times dry weather flow with no infiltration the annual hours of overflowing will be reduced from 225 to 117. However, with infiltration at twice the dry weather flow the reduction will be only to 165 hours/year representing an additional 48 hours/year of overflowing. In terms of the additional volume of runoff escaping as a result of excessive infiltration the effect is much less.

The problem of infiltration involves two basic areas of concern: (1) prevention in new sewers by adequate design, construction, inspection, and testing practices, and (2) the elimination or cure of existing infiltration by proper survey, investigation, and corrective measures. Control of

infiltration in new sewer systems involves engineering decisions and specification of the methods and materials of sewer construction, pipe, joints, and laying procedures and techniques. Correction of existing sewer infiltration can be accomplished by three basic approaches: (1) replacing the defective component, (2) sealing the existing openings, and (3) building within the existing component.

In order to conduct a sewer system evaluation or a system analysis, the following approach is taken:

(1) Identify the scope and nature of the infiltration/inflow problem.

(2) Establish an end objective. (The amount of infiltration/inflow that can be economically eliminated).

(3) Isolate those general sections of the sewer system where infiltration/inflow is occurring.

(4) Formulate a plan which can be economically justified for investigating and locating specific areas from which the major infiltration/inflow emanates.

(5) Formulate a plan which will assure correction of the infiltration/inflow problem along with alternatives for rehabilitation and a prediction of the end results that can be expected.

The costs for an evaluation survey for the determination of excessive infiltration and inflow is summarized in the following table.

TABLE G-15

EVALUATION SURVEY COST ESTIMATES (49)

Phase	Estimated costs per foot for specific areas of sewer system, in 1974 dollars, $
Physical survey	0.15-0.25
Rainfall simulation	0.25-0.50
Preparatory cleaning	0.30-0.90
Internal inspection	0.40-0.70

Based on the findings of survey and the engineers' reports, a decision is made as to which sewers will not need any work, which sewers can be successfully grouted, relined, or replaced to eliminate the sources of infiltration/inflow, and the amount of street repair that will be required.

The correction alternatives include (1) replacement of broken sections, (2) insertion of various types of sleeves or liners, (3) internal sealing of joints and cracks with gels or slurries, and (4) external sealing by soil injection grouting. Additional detailed information is available in recent EPA reports on jointing materials (47,50) and sealants (47,50,51,52).

G.4.2.5.3 Rehabilitation Costs

Rehabilitation costs for any one area is site specific. Generalized estimates, however, may be calculated based on some unit costs for certain classes of repair. The following cost information has been adopted from EPA Report No. 430/9-75-021 (53).

G.4.2.5.3.1 Sewer Replacement Costs

The cost curve for replacing the existing gravity sewer with a new pipe of the same size is shown in Figure G-13. Included in the costs are the costs for site preparation, excavation, backfill, pavement, pipe materials, removal of existing pipe, pipe installation, reconnection of one house service connection for every 20 feet of pipe and field inspection. In deriving the cost curve, it was assumed that the depth of cover over the crown of the pipe is 9 feet, the pipe is laid in moderately wet soil conditions, the excavations are limited to earth excavations and the cost required to remove the existing pipe is 50% of that required to install the new pipe. The cost required for sewage bypassing during construction is not included.

For preliminary estimations, this curve should be sufficient in most applications. For more detailed cost estimations, individual costs should be developed based on the actual field conditions. Factors which may affect the cost for sewer replacement are shown in Table G-16.

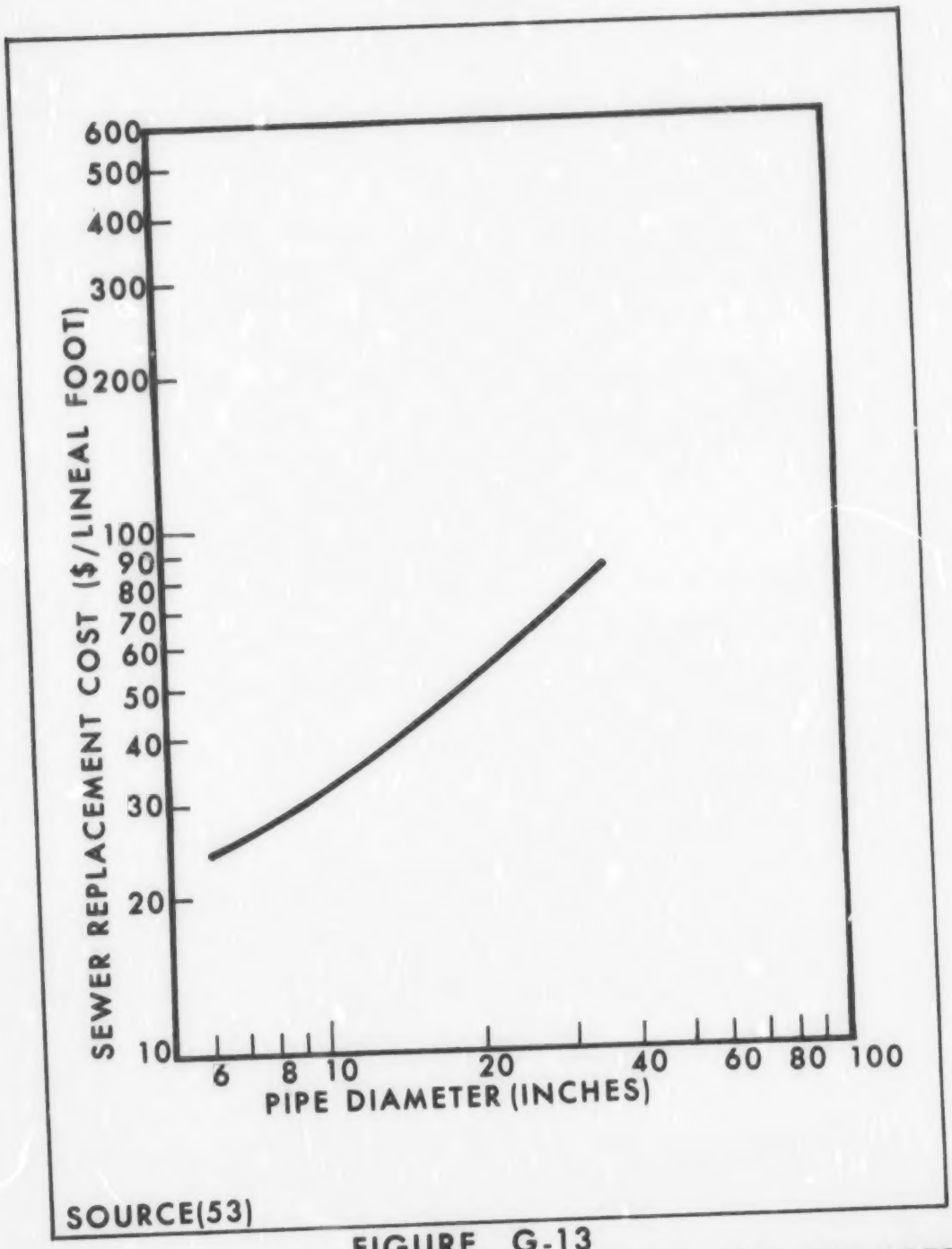

FIGURE G-13
SEWER REPLACEMENT COST VERSUS PIPE DIAMETER

TABLE G-16

SEWER REPLACEMENT COST CRITERIA (53)

Size of pipe
Depth of pipe
Type of service
Type of pipe
Removal of existing pipe
Number of service connections to be made
Groundwater elevation
Proximity to other utilities
Pipe transportation requirements
Infiltration allowance requirements
Access to site work
Availability of storage area for pipe materiald and equipment
Availability of storage area for excavated materials
Weather conditions
Availability and cost of labor

G.4.2.5.3.2 Pipe Lining (Polyethylene) Costs

The cost curve for pipe lining with polyethylene pipe is shown in Figure G-14. Included in the costs are the costs for site preparation, insertion pit, pipe materials, pipe welding, pipe installation, connection of one house service connection for every 20 feet of pipe, pipe sealing off in manholes and mobilization. It was assumed that the depth of cover over the crown of the sewer is 9 feet.

Factors which may affect the pipe lining cost are shown in Table G-17. They should be considered in developing more refined cost data.

G.4.2.5.3.3 Grouting Costs

The costs for chemical grouting of sewer pipes are shown in Figure G-15. The costs are developed based on the following assumptions (54):

(1) Length of manhole section: 300 feet

(2) Type of pipe: Vitrified clay

(3) Depth of flow: Less than 20% of pipe diameter

(4) Type of joint: Factory made

(5) Joint spacing: 4 feet

(6) Access to manholes: Readily accessible

(7) Manhole opening: 21 inches

(8) Manhole diameter: 4 feet

(9) Manhole condition: Structurally sound with steps for access

(10) Manhole depths: 6-8 feet

(11) Hazardous gas: None present

(12) Random vs. successive manhole sections: All sections requiring grouting are successive

(13) Mobilization distance: Within 100 miles

(14) Weather conditions: Mild temperature and [illegible] storm

(15) Traffic control: None required

(16) Chemical grout used: Acrylamide gel or urethane foam

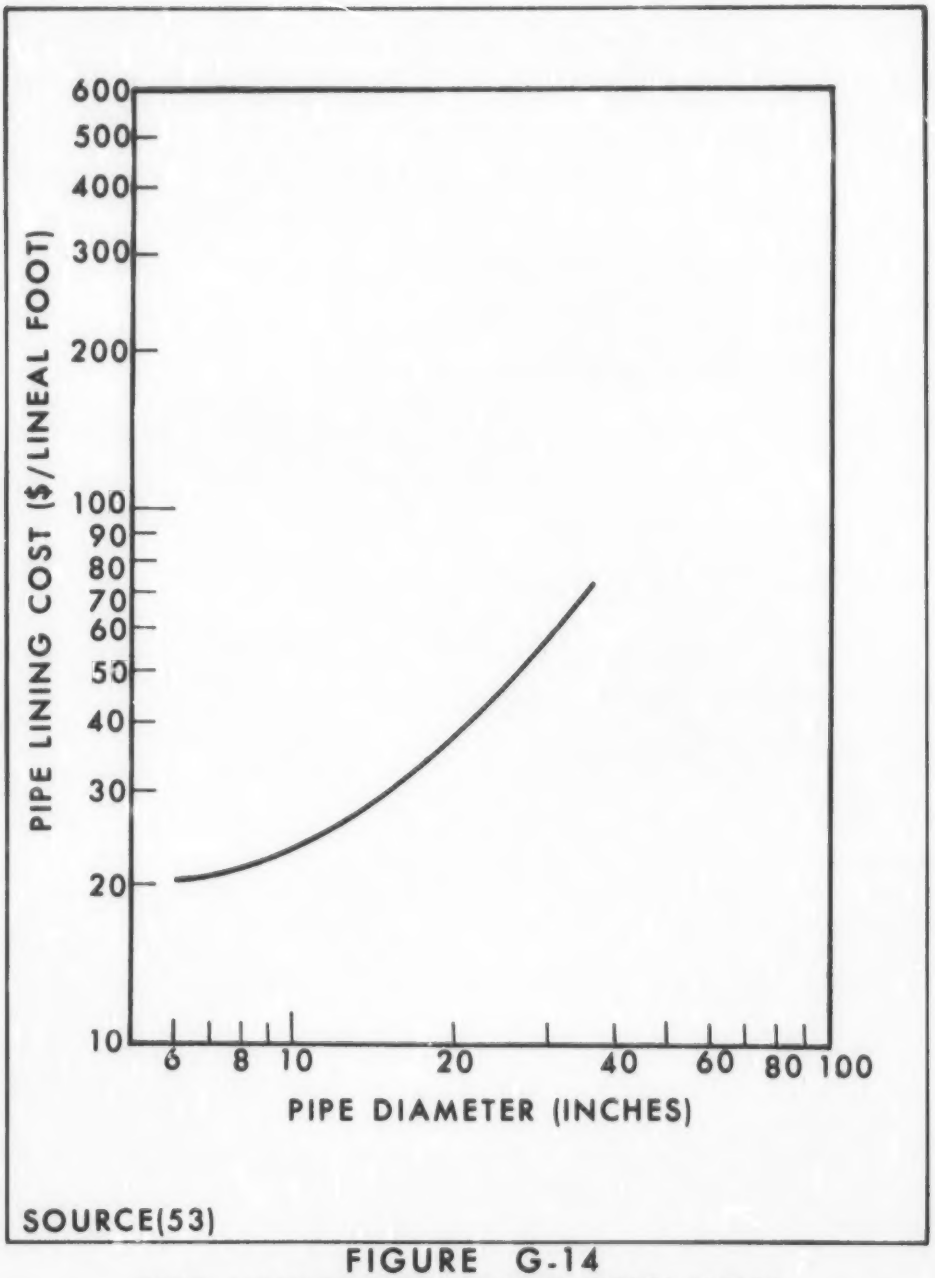

FIGURE G-14
PIPE LINING (POLYETHYLENE) COST
VERSUS PIPE DIAMETER

TABLE G-17

PIPE LINING COST CRITERIA (53)

Size of sewer
Length of sewer
Depth of sewer
Grade and direction change of sewer
Depth of flow in sewer
Size of liner pipe
Liner pipe wall thickness required
Annulus grouting requirements
Number of service connections to be made
Type of surface restoration required
Pipe transportation requirements
Type of manhole "seals" required
Extent of sewer cleaning required
Technique to "prove" or preinspect sewer lines
Excavation requirements
Groundwater elevation
Access to site of work
Availability of electrical power for fusing
Availability of storage area for pipe materials and equipment
Availability of storage area for excavated materials
Mobilization distance
Availability and cost of labor

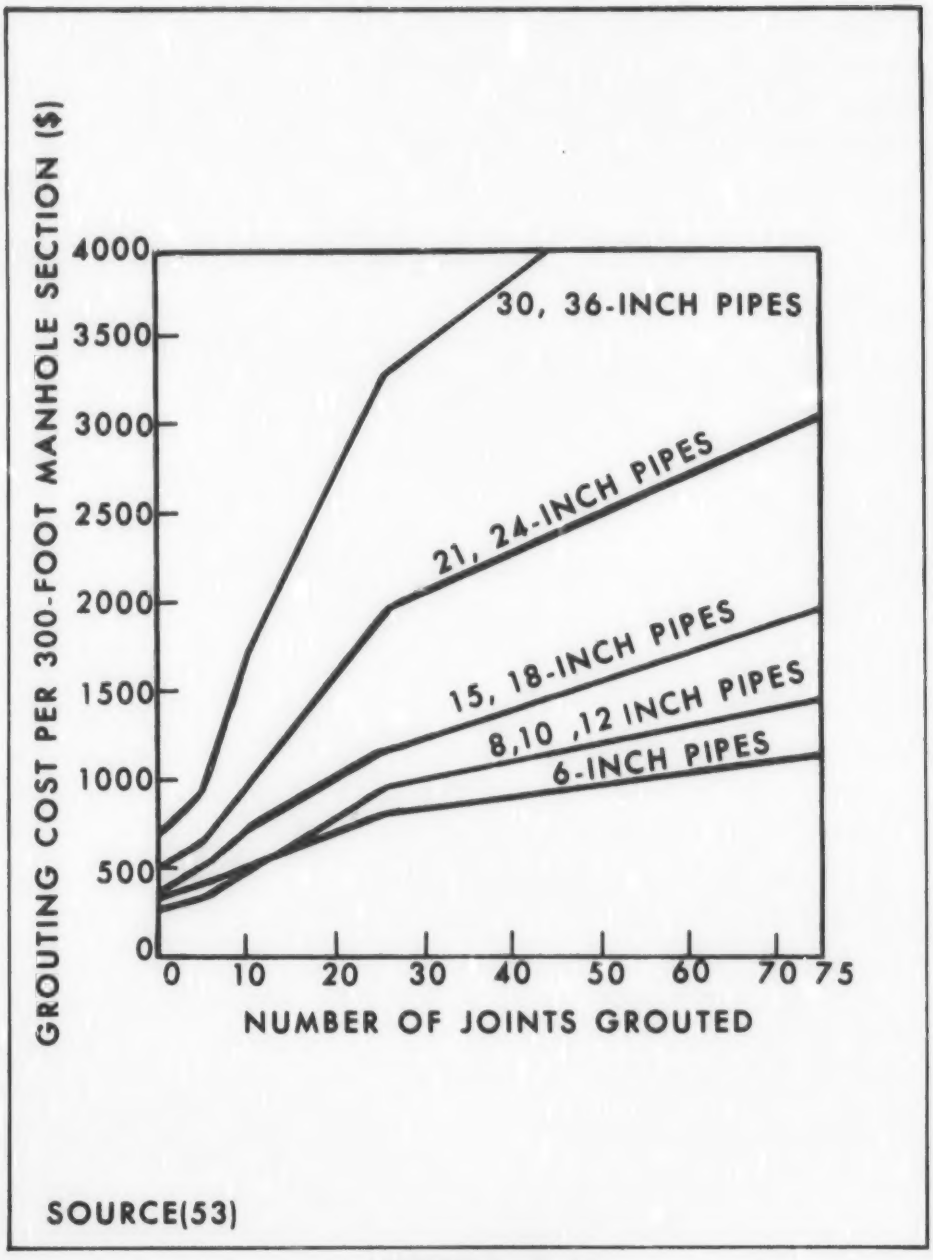

FIGURE G-15
GROUTING COST VERSUS NUMBER OF
PIPE JOINTS GROUTED

TABLE G-18

SEWER LINE GROUTING COST CRITERIA (53)

Mobilization distance
Weather condition
Terrain
Type of soil
Access to manholes
Manhole opening
Manhole size
Manhole cleanliness
Manhole depth
Hazardous gases in manhole
Type of pipe
Pipe size
Pipe alignment
Pipe grade
Pipe cleanliness
Depth of flow
Flow rate
Ability to plug
Type of joint
Joint spacing
Offset joints
Intruding service connections
Structurally damaged pipe
Random vs. successive manhole sections
Availability and cost of labor

G.4.2.6 Sewer Separation

In the 1967 APWA (7) report the cost of sewer separation was shown to vary enormously depending on whether partial or complete separation was being considered. The cost given for partial sewer separation averaged about $25-30 per foot of sewer in December 1976 dollars. Thus, the cost of installing sewers initially based on sewer lengths given in Figure G-2 ranges from about $2800-$5500/acre. Assuming the sewers have a life of 50 years and the interest reat is 6% installed, they will cost from $177 to $394/year. The cost to the homeowner for the house connection will be about one-third of the sewer cost in terms of dollars/capita. Thus, the cost of owning the sewerage system will range from $235/acre-year to $465/acre-year.

The cost of sewer separation in developed areas is much greater. For example, the cost of sewer separation in developed areas was given for several communities by Lager and Smith (2). The cost ranged from a low of about $4800 per acre in Bucyrus, Ohio, to a high of $150,400 per acre in Boston. Nationwide costs for sewer separation ranged from $9,250 to $35,580 per acre. Thus, it appears that sewer separation in highly developed urban areas is essentially impractical but installation of separate sewers at the time the land is developed is a feasible alternative for reducing pollution. At a population of 50,000 the annual cost of owning separate storm sewers costing $27.5 per linear foot is about $194/acre-year.

The pollution control potential for separate sewers can be estimated from the analysis of BOD load sources. About 30% of the annual load is associated with pollutants washed from urban areas and 70% of the load is caused by solids which settle in combined sewers to be washed into the receiving stream later by stormwater. If the load from separate storm sewers is 30 lb BOD/acre-year the corresponding load from combined sewers might be estimated at about 96 lb BOD/acre-year. Thus, by providing separate sewers the reduction in pollution load will be about 66 lb BOD/acre-year. Dividing $194/acre-year by the pollution load removed from the receiving stream (66 lb BOD/acre-year) the cost of BOD removal is about $2.94 per lb of BOD. This analysis applies only if the sewers are constructed in undeveloped land. In the developed area the cost could be greater by a factor of ten.

G.4.3 Loading Control

The potential impact of wet weather pollution discharges from combined sewers can also be limited through collection system management techniques aimed at controlling the quantity of pollutant available for discharge from the sewers.

The analyses of stormwater pollution sources in Section G-2 estimated that the annual BOD load from combined sewers ranges from 80-120 lb BOD/acre-year. Of this amount, 65% or 52-74 lb BOD/acre-year is attributable to municipal sewage solids which settle in sewers and are later flushed into receiving waters by storms. Thus, it is apparent that reasonably effective measures to limit the availability of this material for discharge with overflow will have a significant impact upon the magnitude of stormwater loads.

Three methods of load control will be discussed in this section; sewer flushing, sewer scraping, and catch basin cleaning. The cost effectiveness of structural sewer separation will also be discussed here to provide a cost contrast with the semistructural management approaches. Part II of this appendix also considers sewer flushing in the level I SWMM analysis of best combinations of storage/treatment, street sweeping and catch basin cleaning.

G.4.3.1 Sewer Flushing

Periodic sewer flushing has been proposed as one way of limiting the pollution from combined sewers. The goal of sewer flushing is to maintain the inventory of BOD exerting solids in the combined sewer system at a low level, so that, when storms of sufficient intensity to flush the solids from the sewer occur, the pollutional impact will be minimized. A number of flushing approaches are available, including flushing stations, in-line storage, and portable tanker units.

A flushing station technique developed by FMC (6) involves installation of a watertight bag in existing manholes with pump, valves, and controls to draw screened raw sewage from the sewer for storage in the inflatable bag. The screened sewage in the bag is released periodically with sufficient energy to flush settled solids from the lateral sewer downstream of the flushing station. In-line storage systems have been described by Pisano (55). They involve a system of internal dams which are employed to block the flow of sewage at critical upstream points for instantaneous release of sewage to

scour downstream segments without creating an artificial overflow. The tanker approach merely involves gravity or pressurized dumping of flush water into strategic manholes to provide scouring action.

Because each flushing wave becomes attenuated by wall friction and other internal pipe configuration flushing has limited usefulness beyond certain distances. It has been estimated that up to 1200 feet of small- and medium-diameter sewer can be flushed by a single flush station (56). FMC, in their study, concluded that from two to four flush stations are needed for every nine acres of urban land served by combined sewers. If the miles of sewer per acre is 0.025 (corresponding to an average community size of 170,000, Figure G-2) this would mean flush stations would have to be placed from 297 to 594 feet apart.

Recent studies in Boston, however, have developed a method for estimating pollutant loadings associated with dry weather sewage solids deposition in combined sewer systems (57). The predictive equations relate the total daily mass of pollutant deposition accumulations within a collection system to physical characteristics of collection systems such as per capita waste rate, service area, total pipe length, average pipe slope, average diameter and other more complicated parameters that derive from analysis of pipe slope characteristics. A comparative error analysis of the model for a test case collection system indicated a relative error in predicting solids deposition ranging from 8 to 18%. Suspended solids were also found through regression analyses to be a useful surrogate for BOD, COD, and nutrient forms. An important outcome of the work was the determination of the relationship between the distribution of solids deposition and cumulative pipe length in the system which is reproduced as Figure G-16. The curves reveal that between 80 and 90% of the deposition of suspended solids (and by association, BOD) occurs in only 50% of the system. These curves can be used in a preliminary fashion to estimate the total length of sewer which may have to be flushed.

The location of sewers which will likely benefit from flushing may then be approximated knowing the location of lines with average slopes less than those indicated. Obviously, other factors affect the location in severity

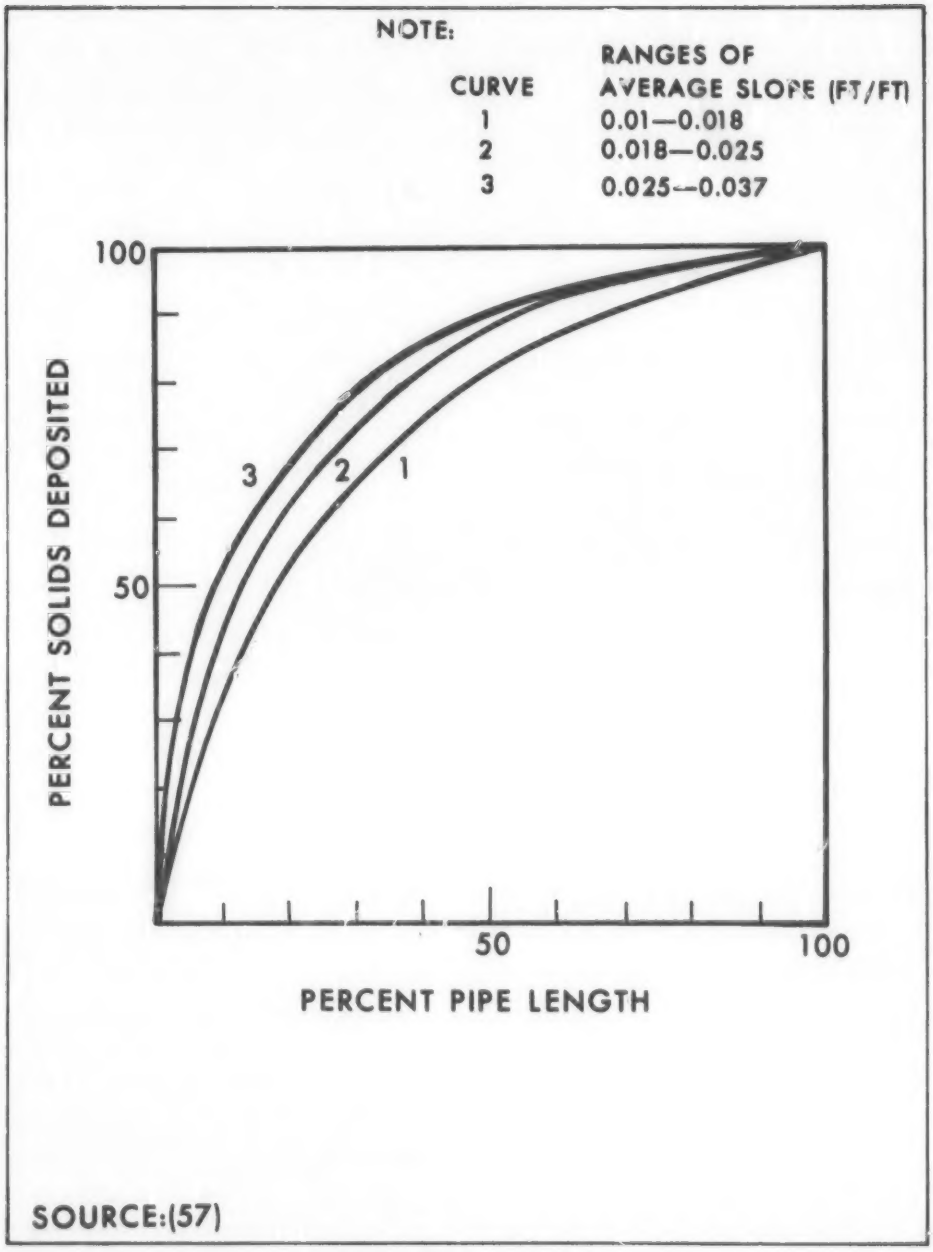

FIGURE G-16
CUMULATIVE DISTRIBUTION OF SOLIDS DEPOSITED VERSUS PIPE LENGTH

of deposits. The reader is referred to the study report to evaluate the specifics of flushing system design (57).

By calculation of daily mass balance in a sewer system the inventory of deposited solids after (n) days of daily flushing may be found to be represented by the following:

$$M_n = L(F_r + F_r^2 + F_r^3 + ...F^n) + M_o F_r \qquad \text{(G-32)}$$

where:

n = number of days

M_n = lbs of solids remaining

M_o = initial lbs of solids

F_r = fraction of solids remaining after each flush

L = daily solids accumulation (lbs/day)

For large values of (n) the last term in Equation (G-32) will approach zero. If the ratio M_n/L is then multiplied by F_r and subtracted from the expression for M_n/L it can be seen that for large values of n Equation (G-32) will approximate the following expression:

$$M_a = LF_r/(1 - F_r) \qquad \text{(G-33)}$$

M_a = mass of BOD stored in the sewers, lb

Flushing experiments conducted by FMC showed that the flushing efficiency ($1-F_r$) ranged from a minimum of 35% to a maximum of about 75% (6). The volumes of water stored in the flushing station ranged from 300 gallons to 900 gallons. The recommended frequency for sewer flushing was once-per-day.

If one applies a cleaning efficiency of 35% (F_r = 0.65) to Equation (G-33) the sewer solids inventory will stabilize (within 1%) at 1.86 times the daily accumulation. When the cleaning efficiency is 50% (F_r = 0.5) the inventory will stabilize within seven days at the daily accumulation and when cleaning efficiency is 75% the inventory will stabilize within four days at one-third the daily accumulation. Therefore, Equation (G-33) can be used in most cases to estimate solids inventory, but for short time intervals between storm events Equation (G-32) can be used to estimate the inventory washed out by

the stormwater. A key factor in estimating the efficacy of sewer flushing is the average time interval between rainfall events of sufficient intensity to cause overflow of the combined sewer. If the design capacity of the treatment plant is based on a production rate of 100 gpd/capita at a population density of 13.1 the size of the plant will be 0.00131 mgd/acre of urban area served. In the interceptor is sized at 3.5 times the treatment plant capacity the capacity of the interceptor 0.00459 mgd/acre. If the runoff coefficient for rate of runoff, as used in the Rational Method, had a value of 1.0 this threshold value of 0.00459 mgd per acre would be equivalent to a rainfall intensity of 0.007 inches per hour. However, it is known that at these low values of rainfall intensity the runoff coefficient is small and the relationship (Equation (G-14)) developed by Davis and Borchardt (39) between rainfall intensity and runoff coefficient shows that the rainfall intensity which will result in a runoff of 0.007 in/hr is near 0.007 in/hr. According to the distribution of hourly rainfall intensities given by Davis and Borchardt (39) rainfall exceeding 0.07 in/hr will occur during about 22% of the rain hours or about 108 hours/year. Thus, the average interval between rainfall intensities which are of sufficient intensity to cause overflow of the combined sewer is about 3.4 days.

In the FMC report (6) on sewer flushing the expected flushing efficiency was estimated at 60-75%. However, to be conservative the once-a-day flushing efficiency will be taken as 50% here. From Equation (G-32) the solids inventory will be 88% of the daily accumulation if the interval between storms is three days and 94% if the interval is four days. Thus, the inventory at an interval of 3.4 days can be estimated at 90.4% of the daily accumulation. The reduction in BOD reaching the stream can then be computed as (3.4 - 0.904)/3.4 or 73.4%. Since the load computed from settled solids was 52-79 lb BOD/acre-year, the BOD reduction is 38-58 lb BOD/acre-year.

A generalized cost of sewer flushing is difficult to estimate, because only limited cost data are available and the number of flushing points per acre is not known with a great degree of assurance. Based on the findings of the Boston study (57) it is likely that the number of flushing points in the system may be less than previously estimated, perhaps closer to the two stations per nine acres reported by FMC (6) rather than four per nine acres.

For the mechanized daily flushing system developed by FMC (6) the cost per unit (or cost per manhole) was estimated at $5500 in 1972 dollars. Thus, the capital cost per acre is about $1250 or approximately $2000 per acre in current dollars. Amortization over 20 years at 6% gives a debt service of $174/acre/year. FMC recommended an operation and maintenance allowance of $102 per month for the two unit per nine acre installation which converted to current dollars becomes roughly $217/acre/year. The total cost under these conditions is then $391/acre/year (debt service plus operation and maintenance). If the previously estimated BOD reduction with daily sewer flushing is used (35-58 lb BOD/acre-year) the cost of sewer flushing will range from $5.75-$10.30/lb BOD/removed.

Sewer flushing can also be done with manual labor. APWA (4) reports that in 1960 all of the sewers in Chicago were flushed approximately 3.2 times/year. The cost of flushing was estimated in 1960 dollars as $42 per mile of sewer flushed. Assuming 0.025 miles of sewer per acre, the cost of manually flushing all sewers once would be $1.05/acre in 1960 dollars or $2.65/acre in current dollars. The annual cost of daily flushing in current dollars would be $967/acre-year. This estimate is higher than the estimate for automatic sewer flushing but if the flushing was done every two days, the cost of manual flushing might be competitive with automatic flushing.

G.4.3.2 Catch Basin Cleaning

Catch basin cleaning is one of the most discussed nonstructural pollution control measures. The potential for pollution abatement by this method, however, is likely to be small.

Historically, the role of catch basins was to minimize sewer-clogging by trapping coarse debris and to reduce odor emanations from the sewers by providing a water seal. In early sewer systems, catch basins were important because of the number of impaired streets, the use of flat grades, inefficient means of sewer-cleaning, and low flows in the sewer systems. With improvements in street surfacing, attention to design for self-cleaning velocity in sewers, and the advent of street sweeping and improved sewer-cleaning techniques, their benefits have been reported as being marginal.

Despite the purported reduced need, catch basins remain very prevalent in many sewer systems. The APWA report (4) on street accumulation reported that Chicago had 3815 miles of sewer in 1960 with 200,000 catch basins. The AVCO report on stormwater pollution in Tulsa reported 330 miles of installed sewers with 22,000 catch basins (58). Thus, the average number of catch basins in Chicago was 52.4/mile of sewer in Chicago and 66.7/mile of sewer in Tulsa. Averaging these gives an estimate of 60 catch basins/mile.

The Metcalf and Eddy report on catch basin technology (59) quoted a 1928 survey of catch basin dimensions conducted by American City Magazine. Ninety-six American cities, the District of Columbia, and four Canadian cities participated in the survey. The average catch basin volume available for storage of solids and water was 1.45 cu. yds. The APWA report of street accumulation quoted catch basins cleaning statistics for the City of Chicago in the period 1946-1960. The average amount of material removed from each catch basin was 0.7 cu yd/yr. The cleaning frequency was once or twice per year. Thus, it appears that when catch basins are cleaned about once a year, the available volume is about 50% water and 50% solids. The solid material is wet with a density of about 110 lb per cu. ft.

The best data on the amount of pollution contained in uncleaned catch basins is given by Sartor and Boyd (9). Twelve uncleaned catch basins in San Francisco were completely stirred and the BOD concentration of the slurry was measured. The BOD concentrations ranged from 5 mg/l to 1500 mg/l with an average of 241 mg/l. The amount of water in a single catch basin just before annual cleaning is about 1 cu. yd. Using the average BOD concentration of 241 mg/l, the uncleaned catch basin will contain about 0.4 lb of BOD. Assuming 60 catch basins per mile of sewer and 0.025 miles of sewer per acre, this is equivalent to 0.61 lb BOD per acre. Assuming that the catch basins are cleaned annually, the amount of pollution removed in the cleaning process will be 0.61 lb BOD/acre-year. This constitutes only about 2% of the previously estimated 25-35 lb BOD/acre/year for separate storm sewers. Part II of this appendix also contains an analysis of catch basin effectiveness based on an assessment by Lager and Smith (2). The analysis reveals that for twice-per-year catch basin cleaning the expected

level of BOD removal from stormwater discharges would be slightly greater than 5%.

Sartor and Boyd (9) also flushed uncleaned catch basins with clean water at rates corresponding to storms with intensities ranging from 0.07-0.7 in/hr. The catch basins contained from 2000-3000 lb of solids. It was found that only about 1% of the solids were removed by the flushing effect. Thus, it appears that solids which accumulate in catch basins which are primarily inorganic are not readily flushed out by rainfall events.

The potential for reducing the amount of pollution which reaches the stream from separate storm sewers by means of catch basin cleaning is apparently small. The amount of inorganic solids which can be intercepted in catch basins, however, is a much larger percentage of the total solids loading. For example, the APWA report on street accumulation (4) estimated the amount of dust-and-dirt on the streets as 1.5 lb/day/100 ft of curb. Assuming the sewer length equals the street length and applying the factor of four mentioned previously, the amount of dust-and-dirt believed to be washed into the storm sewer is about 231,000 l/yr per mile of sewer. Annual cleaning catch basins in Chicago yielded about 0.7 cu. yd. of material which was 60% solids. Assuming 60 catch basins per mile, this is equivalent to a removal of about 75,000 lb. of solids per mile of sewer annually. This represents about 32% of the estimated annual load of dust-and-dirt.

Some cost information is available for cleaning of catch basins. The cost of catch basin cleaning in Chicago was given by APWA as $3.50 per catch basin cleaned in 1960 dollars. Catch basin cleaning costs in Buffalo, New York ranged from $4.59 in 1966-67 to $7.61 per catch basin in 1970-71 (60). The Chicago costs adjusted to December, 1976 become $8.80 per catch basin, and the Buffalo equivalent cost is $11.23. Sartor and Boyd (9) surveyed catch basin cleaning practice in seven cities and found that the cost of catch basin cleaning (1971) was $15.00 for hand-cleaning and about $7 per catch basin for mechanical cleaning. An average cost of $10/catch basin will be used here.

Lager and Smith (59) reported the results of an APWA survey of 299 cities which showed an average cleaning frequency of 2.3 times/year. Of the seven

cities surveyed by Sartor and Boyd (9) two reported a frequency of 2.3 times/year, two at a frequency of once a year, one at six times/year, and the remainder "as required".

Assuming a cleaning frequency of 2.3 times/year, 60 catch basins per mile, 0.025 miles of street/acre, and a cost of $10 per cleaning gives an overall cost for catch basin cleaning of $34.50/care-year. Divising the cost per acre-year by the estimated 0.61 lb BOD/acre-year gives the cost of BOD removal at $56.50 per lb of BOD removed. Therefore, it would appear that not only is the potential effectiveness of catch basin cleaning small but the cost is high.

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APPENDIX G, PART II

EPA-600/2-77-083
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STORM WATER MANAGEMENT MODEL: LEVEL I--COMPARATIVE EVALUATION OF STORAGE-TREATMENT AND OTHER MANAGEMENT PRACTICES

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FOREWORD

The US Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solving and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communication link between the researcher and the user community.

Combined sewer overflows and urban stormwater discharges are a significant pollution source. This report describes simplified procedures to enable decision makers to obtain a preliminary estimate of the magnitude of this pollution source and the associated costs of control.

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PREFACE

This report is part of a series of documents on urban stormwater management which provides analysts with a wide variety of tools for evaluating alternatives ranging from simple desktop procedures as outlined in this report (Level I analysis) to sophisticated computer-based simulation using the original Storm Water Management Model (Level IV analysis). The companion document to this simplified procedure for comparing other management practices with storage-treatment options would be very useful in supplementing this report. The other report is titled:

> Heaney, J.P., W.C. Huber, and S.J. Nix, Storm Water Management Model: Level I--Preliminary Screening Procedures, EPA-600/2-76-275, Environmental Protection Technology Series, USEPA, 1976.

ABSTRACT

The original USEPA Storm Water Management Model (SWMM) provides a detailed simulation of the quantity and quality of stormwater during a specified precipitation event lasting a few hours. This model is widely used. However, it is too detailed for many purposes. Indeed, a wide range of evaluation techniques ranging from simple to complex procedures are needed. In particular, the 208 planning effort needs simplified procedures to permit preliminary screening of alternatives. In response to this need, four levels of stormwater management models are being prepared. This volume presents a "desktop" procedure to compare selected alternative control technologies.

A graphical procedure is described which permits the analyst to examine a wide variety of control options operating in series with one another or in parallel. The final result is presented as a control cost function for the entire study area which is the optimal (least costly) way of attaining any desired level of control. Given a specification regarding the desired overall level of control the user can determine the appropriate amount of each control to apply.

This methodology is applied to Anytown, U.S.A., a hypothetical community of 1,000,000 people. The results indicate the mix of treatment, storage, street sweeping, and sewer flushing which attains the specified pollution control level at a minimum cost.

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LIST OF SYMBOLS

A_p	Area served by option p, ac
A_{SF}	Area served by combined sewers to be flushed, ac
A_{SW}	Area to be swept, ac
AR	Annual runoff, in/yr
$\alpha(i,j)$	Coefficient for storm and unsewered areas for pollutant j on land use i, lb/ac-yr-in
$\beta(i,j)$	Coefficient for combined areas for pollutant j on land use i, lb/ac-yr-in
C_p	Cost per unit of effort, $\$/X_p$-yr
C_{SF}	Cost per mile of sewer flushed, $/mile
C_{SW}	Cost per curb mile swept, $/curb-mile
CF_p	Total cost function for option p
DD	Daily dust and dirt accumulation rate, lb/day
DS	Annual depression storage, in/yr
DWF	Dry-weather flow, in/yr
ϵ	"Pick-up" efficiency of the street sweeping equipment
F	Pounds of pollutant per pound of dust and dirt
$f_i(PD_d)$	Population density function for land use i
G	Gutter density, curb-miles/ac
I	Total imperviousness, percent
I_S	Imperviousness due to streets only, percent
M_{DEP}	Combined sewer deposition pollutant (BOD) load, lb/yr

LIST OF SYMBOLS (CONTINUED)

M_P	Pollutant load in area served by option p, lb/yr
M'_p	Pollutant load available to option p, lb/yr
M_{II}	Pollutant load available to all parallel options , lb/yr
M_W	Wet-weather pollutant (BOD) load, lb/yr
MC_p	Marginal cost per pound of pollutant removed by option p, $/lb
MC_{II}	Composite marginal cost per pound of pollutant removed by the parallel options , $/lb
MF_p	Marginal cost function for option p
MF_{II}	Composite marginal cost function for the parallel options
m_{Dw}	Annual dry-weather BOD load, lb/ac-yr
m_{DEP}	BOD load of combined sewer deposition, lb/ac-yr
m_p	Unit pollutant load in area served by option p, lb/acre-yr
m_W	Annual wet-weather pollutant (BOD) load, lb/ac-yr
N_D	Number of dry days since the last storm
N_S	Number of days between street sweepings
n	Number of times the streets were swept since the last storm
P	Annual precipitation, in
P_1	Total pollutant at the beginning of the storm, lb
P_o	Pollutant remaining at the end of the last storm, lb
PD_d	Population density in the developed area, persons/ac
PF_p	Production function for option p
ϕ_p	Fraction of pollutant load available to option p ($0 \leq \phi_p \leq 1.0$)
ϕ_{SF}	Fraction of wet-weather BOD load available for flushing ($0 \leq \phi_{SF} \leq 1.0$)
ϕ_{SW}	Fraction of wet-weather BOD load available for sweeping ($0 \leq \phi_{SW} \leq 1.0$)

LIST OF SYMBOLS (CONCLUDED)

W_E	Net pollutant (BOD) discharge, lb/yr
W_p	Pollutant removal by option p, lb/yr
W_{II}	Pollutant removal by the parallel options , lb/yr
W_{SF}	BOD load in deposition removed by daily sewer flushing, lb/yr
W_{ST}	Wet-weather BOD removed by sweeping, lb/yr
$\overline{X}$	Input vector
X_p	Level of effort for process p ($0 \leq X_p \leq 1.0$)
X_{SF}	Fraction of combined sewerage system components flushed daily ($0 \leq X_{SF} \leq 1.0$)
X_{ST}	Input vector to storage-treatment option ($0 \leq X_{ST} \leq 1.0$)
X_{SW}	Fraction of days per year an area is swept ($0 \leq X_{SW} \leq 1.0$)
$\overline{Y}$	Output vector
Y_p	Fraction of available pollutant load removed by option p ($0 \leq Y_p \leq 1.0$)
Y_{II}	Fraction of pollutant removed by the parallel options ($0 \leq Y_{II} \leq 1.0$)
Y_ψ	Fraction of pollutant removed by the serial operation ($0 \leq Y_\psi \leq 1.0$)
Y_{SF}	Fraction of available BOD removed by flushing ($0 \leq Y_{SF} \leq 1.0$)
Y_{ST}	Fraction of BOD removed by storage-treatment ($0 \leq Y_{ST} \leq 1.0$)
Y_{SW}	Fraction of available BOD removed by sweeping ($0 \leq Y_{SW} \leq 1.0$)
Z_p	Total cost for process p, $/yr
Z_{II}	Composite total cost of the parallel options , $/yr
Z_ψ	Composite total cost of the serial operation, $/yr
Z_{SF}	Total cost of combined sewer flushing, $/yr
Z_{ST}	Total cost of storage-treatment, $/yr
Z_{SW}	Total cost of sweeping, $/yr

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SECTION I

SUMMARY

Analysis of wet-weather pollution control alternatives is much more complicated than the traditional dry-weather sewage problem due to the highly variable flow and the much broader range of options to be evaluated. The highly variable nature of the flows requires statistical characterization of the properties of the runoff hydrographs and pollutographs using averaging times ranging from a single storm event to an annual series. The range of control options has been extended from examining only storage and treatment devices to inclusion of other management practices, e.g., street sweeping, sewer flushing, catch-basin cleaning. These units operate in series and/or in parallel with one another.

This report provides a simplified methodology for evaluating these other management practices in conjunction with storage-treatment options. A graphical solution technique is used to evaluate wet-weather control alternatives for Anytown, U.S.A., a typical U.S. city of 1,000,000 people. The results demonstrate the technique and provide a preliminary indication regarding the relative competitiveness of the various control options.

GENERAL THEORY AND METHODOLOGY

The optimal combination of storage-treatment devices and other management practices for wet-weather pollution control can be determined using marginal analysis from economic theory, and a graphical solution procedure. Marginal analysis indicates that more intensive use should be made of control alternatives with lower marginal costs, measured in dollars per pound of pollutant removed. As these activities are expanded, marginal costs increase to the point where other options become competitive. The entire analysis can be viewed as determining, at any specified marginal cost, the quantity of pollution which the various control options, in parallel, would offer to control. These results, for all options in parallel, are combined to yield a composite control cost curve. Then this composite option is evaluated with the downstream option(s) in series with it to yield the final result. The solution is guaranteed to be optimal because every option produces a diminishing marginal value of pollution control as its level of effort is expanded. For example, if sewer flushing is to be used as a control alternative the initial monies will be spent where it is most effective, e.g., cleaning the pipes with the heaviest deposition rate. As more money is spent, controls would be used on progressively cleaner sections of pipe. Thus, the pollution control effectiveness, per dollar invested, would

decrease. Also, constant unit control costs are assumed. As a consequence, marginal costs increase thereby guaranteeing that the control cost functions are convex and the resulting graphical solution is the optimal one.

CONTROL TECHNOLOGIES

For the purposes of this study, four technologies were considered: street sweeping, combined sewer flushing, catch-basin cleaning, and storage-treatment. Only combined sewered areas utilize all four technologies. Storm sewered areas do not require sewer flushing. In addition to flushing, unsewered areas do not use catch-basin cleaning or street sweeping if it is assumed that there are no gutters.

For street sweeping, an overall BOD removal efficiency of 0.5 is assumed. The assumed unit cost is $7.00/curb-mile swept ($4.35/curb-km). The performance of sweepers was estimated, for varying sweeping intervals and removal efficiencies, using a continuous simulation of one year of data for Minneapolis. A modified version of the street sweeping procedure described in SWMM was used.

Data on combined sewer flushing were obtained from studies in Boston, Mass. The results of these efforts indicated that a relatively small percentage of the pipes retain a substantial amount of the total deposition. The assumed annual costs of flushing per unit length of sewer line is $11.78/ft ($38.64/m). Daily flushing is assumed to remove 100 percent of the BOD deposited in the affected pipes.

Catch basins were found to be relatively ineffective as a wet-weather pollution control device due to their relatively small size in relation to the contributing drainage area. Thus, they were not investigated further.

The procedure for evaluating storage-treatment technologies was presented in our earlier work. Thus, this control technology was not discussed in detail.

APPLICATION TO ANYTOWN, USA

The methodology was applied to a hypothetical urbanized area, called Anytown, which has characteristics typical of the 248 urbanized areas in the US as listed below:

(1) Population Density (urbanized area): 5.14 persons/ac (12.70 persons/ha)

(2) Mean Annual Precipitation: 33.4 in (84.8 cm)

(3) Land Use Percentage (urbanized area): residential, 31.4%; commercial, 4.6%; industrial, 8.0%; other developed, 9.8%; undeveloped, 46.2%.

(4) Land Use Percentage (developed areas only): residential, 58.4%; commercial, 14.8%; industrial, 8.6%; other developed, 18.2%.

(5) Percent of Developed Area Served by Type of Drainage System: combined sewers, 14.4%; storm sewers, 38.3%; unsewered, 47.3%.

(6) Population Density of the Developed Area by Type of Drainage System--person/ac (persons/ha): combined, 16.7 (41.3); storm, 13.0 (32.1); unsewered, 4.6 (11.4); all developed areas, 9.6 (23.7).

The results of this analysis, presented by type of sewerage system, are shown in Table 1. Although the combined sewered area comprises less than 15 percent of the land area, about 40 percent of the total costs are incurred for this area because the loadings are higher and it is more cost-effective to control this portion of the total load.

A breakdown of total control costs, by type of technology and assumed availablility factors, is presented in Table 2. For the medium availability factors, storage-treatment is used for about 80 percent of total control. As expected, sweeping and flushing gain in relative importance as the availability factors increase. This effect is most pronounced for street sweeping. This type of sensitivity analysis is quite helpful in providing an indication of the importance of reliable estimates of the availability factors.

Lastly, the significance of the savings resulting from using management practices other than storage-treatment are evaluated in Table 3. The results indicate savings (relative to using storage-treatment only) of 6 percent, 21 percent, or 37 percent for 50 percent control for low, medium, and high availability factors, respectively. These results definitely indicate the need to evaluate all available control options in area-wide wastewater management planning.

TABLE 1. ANNUAL COST OF OPTIMAL STRATEGY FOR ANYTOWN, U.S.A., PRESENTED BY TYPE OF SEWERAGE SYSTEM - MEDIUM AVAILABILITY FACTORS

Type of System	Acreage[a] ac(ha)	Total Annual Cost ($ x 10^6/yr) for Indicated % BOD Control			
		25%	50%	75%	85%
Combined	15,100 (6,110)	0.48	1.65	4.50	7.86
Storm	40,100 (16,230)	0.12	0.82	3.56	7.43
Unsewered	49,500 (20,030)	0.56	1.42	2.82	2.82
Total	104,700 (42,370)	1.16	3.89	10.88	18.11

[a]Anytown has a population = 1,000,000

TABLE 2. ANNUAL COST OF OPTIMAL CONTROL STRATEGY FOR ANYTOWN, U.S.A., PRESENTED BY TYPE OF CONTROL TECHNOLOGY FOR DIFFERENT ASSUMED AVAILABILITY FACTORS.

Type of Control Technology	Total Annual Cost ($ x 10^6/yr) for Indicated % BOD Control and Assumed Availability Factors											
	25%			50%			75%			85%		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Sweeping	0	0.16	0.24	0.21	0.59	0.88	0.56	1.45	2.84	0.94	2.58	3.80
Flushing	0.14	0.14	0.18	0.17	0.21	0.28	0.26	0.57	0.60	1.01	0.69	0.82
Storage-Treatment	1.18	0.86	0.43	4.25	3.09	1.95	11.50	8.86	5.25	19.31	14.84	9.72
TOTAL	1.32	1.16	0.85	4.63	3.89	3.11	12.32	10.88	8.69	21.26	18.11	14.34

TABLE 3. COMPARISON OF ANNUAL COST OF OPTIMAL CONTROL STRATEGY FOR ANYTOWN, U.S.A., USING STORAGE-TREATMENT ALONE AND IN COMBINATION WITH OTHER MANAGEMENT PRACTICES.

%BOD Control	Annual Cost ($ x 10^6/yr)				% Savings Over Storage-Treatment Only		
	Storage-Treatment (S-T) Only	Storage-Treatment and Other Options					
		Low	Medium	High	Low	Medium	High
25	1.47	1.32	1.16	0.85	10	21	42
50	4.95	4.63	3.89	3.11	6	21	37
75	13.39	12.32	10.88	8.69	8	19	35
85	22.42	21.26	18.11	14.34	5	19	36

SECTION II

RECOMMENDATIONS

This simplified methodology for evaluating urban stormwater pollution control alternatives is intended to serve as a preliminary screening device. It requires neither a computer nor an understanding of more refined analytical solution procedures. After the user understands the concepts and procedures, he may wish to substitute the appropriate analytical procedures using derived functions.

The results indicate significant savings if other management options are combined with storage-treatment options. Further savings can be realized by recognizing that a significant portion of the control costs can be assigned to other purposes.

SECTION III

INTRODUCTION

In recent years there has been the realization that stormwater from urban areas is a serious water pollution source. Abatement of this source will require a monumental effort in research, development, and implementation. In this study, a simple methodology is developed which provides a "first-cut" evaluation of the problem and the optimal control strategy.

Several technologies are available to control stormwater pollution. At present, emphasis is placed on storage-treatment control techniques [1]. However, other techniques are available, e.g., street sweeping, sewer flushing. These methods, used in conjunction with storage-treatment, may provide a more cost-effective pollution management package [2, 3, 4, 5, 6]. The resultant optimal mix of all control options is often referred to as "Best Management Practice" or BMP's.

With the potential control effectiveness of options other than storage-treatment established, the need has arisen for a methodology capable of determining, on a "first-cut" basis, the most cost-effective usage of these other options in conjunction with (or exclusive of) storage-treatment in the urbanized area. "First-cut" or preliminary analyses establish the magnitude of the problem and rapidly evaluate alternatives. This study derives a relatively simple methodology to obtain this "first-cut."

Several analytical techniques which can provide an optimal "mix" of control alternatives are available. Many require the use of computerized algorithms which defeat the need for simplicity. Nearly all require an accurate knowledge of the functional form of empirically derived relationships. A simple methodology was developed by Heaney, Huber, and Nix [7] but was limited to storage-treatment as a control alternative.

A graphical technique is chosen to provide a preliminary estimate of an optimal stormwater pollution control strategy. Graphical solution techniques do have drawbacks. They are relatively time consuming and more susceptible to human error. Nevertheless, there are definite advantages. Computational aides are not necessary and complex analytical procedures are avoided.

The next section presents a generalized description of a typical 208 planning area. Section V describes the procedure used to obtain an optimal strategy along with the economic theories used to derive the methodology. This procedure is applicable to a wide variety of stormwater pollution

control networks. Section VI discusses the various control technologies and develops the production functions and cost equations necessary for the methodology of Section V. Section VII is an application of the methodology to a hypothetical urban area known as Anytown, USA. Anytown is given the characteristics found for urbanized areas around the nation [1]. The optimal integrated control package is determined for this hypothetical situation. Appendix A presents a simplified method for estimating wet-weather quantity and quality. Equations to estimate dry-weather quantity and quality are also given for comparative purposes. Lastly, working curves for the application to Anytown are placed in Appendix B.

SECTION IV

208 PLANNING AREAS

The Federal Water Pollution Control Act Amendments of 1972 (PL92-500) are a comprehensive piece of legislation designed to implement a procedure by which virtually all sources of pollution to the nation's waters are to be eliminated and the purity of these waters restored [8]. The pollutants are discharged from both urban and rural areas and from point and nonpoint sources. Several goals were set forth by the Act:

(1) that the discharge of pollutants into navigable waters be eliminated by 1985;

(2) that a level of water quality be attained by July 1, 1983, that provides for the protection of aquatic life, wildlife, and recreation; and

(3) that areawide water quality management planning processes be developed and utilized.

Other provisions include funding for the necessary research and to aid in the implementation of management plans.

Section 208 of the Act sets overall guidelines for the development of areawide planning processes. The US Environmental Protection Agency, designated to carry out the intent of the Act, has published specific guidelines to aid local authorities in attaining the overall goals [9]. These guidelines state that the 208 planning procedure should proceed along the following lines:

(1) Identify the problems in meeting the 1983 goals of the Act.

(2) Identify all constraints and priorities pertaining to the 208 planning area.

(3) Identify all possible solutions to the problems.

(4) Develop alternative plans to meet the statutory requirements.

(5) Analyze the alternative plans for technologic and economic feasibility.

(6) Select an areawide plan.

(7) Seek approval for the plan.

(8) Periodically update the plan.

The selection of a specific plan should be based on cost effectiveness, feasibility, and public acceptance.

An important portion of the selected plan should be involved with the control of stormwater pollutant discharges. EPA guidelines specifically state the need for "an analysis of the magnitude of existing and anticipated urban stormwater problems" [9]. Additionally, techniques to better manage the existing drainage systems, thus preventing discharges at the source, and/or improved methods for the storage and treatment of urban runoff, should be developed.

Areawide management is conducted at the local level. In general, areawide plans should be developed for a region relatively homogeneous in its wastewater problems and ultimate discharge locations. Such an area will include one or several urbanized areas which are of primary concern to this study. In order to conduct an analysis of stormwater discharges from these areas and potential control strategies, a comprehensive inventory of the characteristics of each should be available. For the preliminary or "first-cut" analysis conducted in this study, these characteristics should include land use, sewerage system service areas and population served by each, and the mean annual precipitation.

A definition of an urbanized area is needed to properly delineate the areas of potential urban stormwater discharge. The U.S. Census describes an urbanized area as follows [10]:

(1) A central city (or adjacent cities) of 50,000 or more inhabitants.

(2) Settled areas in close proximity to the central city, including the following:

a. Incorporated areas of 2,500 or more inhabitants or less than 2,500 if the area includes 100 or more closely settled housing units.

b. Small parcels of land with a population density greater than 1,000 (386) inhabitants per square mile (km).

c. Other small parcels of unincorporated land with less than the required population density that eliminate enclaves.

With this definition, the local planner can divide the urbanized acreage among five land use categories: residential, commercial, industrial, other developed (parks, institutions, etc.), and undeveloped. The definition of

an urbanized area allows for the inclusion of large areas of undeveloped lands not likely to be developed in the planning future. These areas should not be included in the following analysis. Additionally, the planner should delineate the area and population served by combined and storm drainage systems and unsewered areas within the remaining developed (or developing) area. With these data, the following graphical procedures may be applied to provide a "first-cut" evaluation of the urbanized area's stormwater problem and optimal control strategy.

SECTION V

GENERAL THEORY AND METHODOLOGY

This section presents the economic theories and general methodology necessary to determine an optimal stormwater pollution control strategy. The discussion is based heavily on production theory and marginal analysis from economics.

THEORY

Marginal Analysis

In its simplest terms, marginal may be defined as "extra." In economic terms, for example, marginal cost is defined as the extra cost associated with an additional unit of some commodity. In economic decision making marginal analysis determines whether an action results in a sufficient additional benefit to justify the additional cost.

Two basic rules governing the concept of marginal analysis are [11]:

(1) The scale of an activity should, if possible, be expanded so long as its marginal net yield (taking into account both benefits and costs) is a positive value; and the activity should therefore be carried to a point where this marginal net yield is zero.

(2) For optimal results, activities should, whenever possible, be carried to levels where they all yield the same marginal returns per unit of effort (cost).

As an example of rule (2), assume that product A, at a specific production level, is yielding $1.50 per $1.00 spent and product B is returning $2.00 per $1.00 spent. In this situation the firm is missing the opportunity to gain $0.50 by not transferring the $1.00 spent to manufacture product A to product B. Therefore, to assure the maximum return, both products should be manufactured at levels of equivalent marginal return or yield.

In stormwater pollution control these same concepts apply. Analysts should seek, in such cases, to utilize various control procedures at levels yielding an equivalent marginal cost.

Production Theory

A production process seeks to increase the utility of a commodity or commodities. In any such process certain technological relationships restrict the decision maker's options on input and output levels [12]. Consider an input vector to a production process, $\overline{X}$, defined as

$$\overline{X} = (X_1, X_2, \ldots, X_i, \ldots, X_n). \quad (1)$$

Similarly, the output vector, $\overline{Y}$, is defined as

$$\overline{Y} = (Y_1, Y_2, \ldots, Y_j, \ldots, Y_m). \quad (2)$$

The technological relationship between the input and output vectors, known as the production function, is

$$\overline{Y} = PF\ (\overline{X}) \quad (3)$$

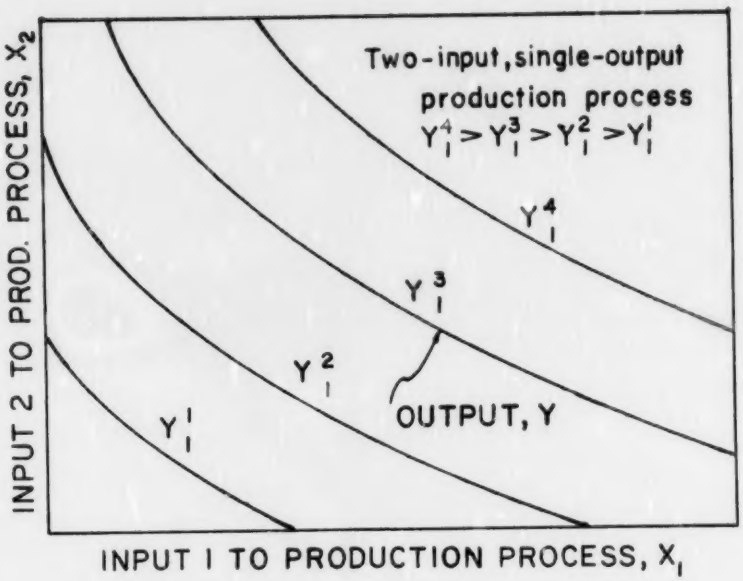
where $\overline{Y}$ is the maximum output attainable with input vector $\overline{X}$. In other words, any output Y_j may not be increased without a reduction in some other output Y_k or an increase in some input X_i. Examples of production functions are shown in Figure 1. The single-input, single-output production function shown may be viewed as a two-input, single-output function with one input held constant.

The shape of the production function is governed by the "law" of diminishing returns which states that, as an input to a production process is increased, with all other inputs held constant, a point will be reached beyond which any additional input will yield diminishing marginal output. For example, if a treatment plant experiences increases in raw sewage flow and no alterations are made to the facility, a flow will be reached where an increment in flow will result in a diminishing increase of pollutant removed.

METHODOLOGY

In this study, a stormwater pollution control option is defined as a unique set of conditions and control technologies. For example, although a particular control technology, such as street sweeping, may be used in several different subareas within an urbanized area, those subareas may have varying pollutant loading rates which affect the cost-effectiveness of the common technology. Also, within a particular subarea there may be several distinct pollutant sources requiring different control technologies.

Knowing the production function for each stormwater pollution control technology (production process) and with the control options defined, it is possible to graphically determine an optimal strategy. In the discussion that follows all production functions have been transformed into a single-input, single-output form and expressed in terms of the fraction of available pollutant removed, Y, as a function of the fraction of the level of effort, X. The definition of level of effort is dependent on the particular technology. For example, the level of effort for street sweeping is defined as the fraction of days during a year when sweeping occurs. All production functions and later functions or graphs are derived on an annual basis.



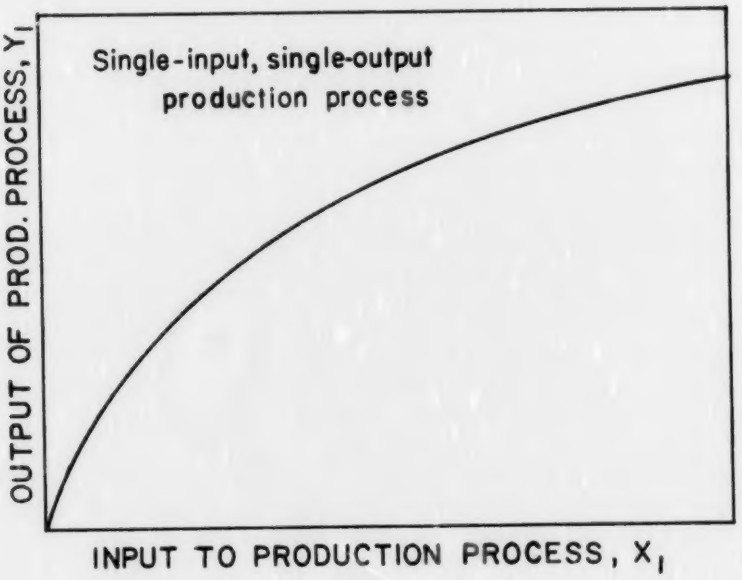


Figure 1. Production Functions

Before delving into the methodology a few more definitions are required.

In stormwater pollution control, options may operate in parallel, series, or a combination of both. A parallel operation is defined as one in which the effluent (untreated portion) of any one option does not act as the influent to any other parallel option. A serial operation is defined as one in which options are sequential with the effluent from one option acting as the influent to the next.

A network of series/parallel pollution control options is shown in Figure 2. In this example four options (p = 1, 2, 3, and 4) operate in parallel followed by one option (p = 5) operating in series with the parallel group. The pollutant flows through this network are shown in terms of the pollutant load in the area served by the parallel options, M_p, the fraction of the pollutant load available to option p, ϕ_p, and the pounds removed by each option p, W_p. The pollutant load available to each option, M_p', is the product of ϕ_p and M_p. The pollutant load M_4' is shown as the influent to an imaginary option (p = 4) that has zero pollutant removal capacity. This simply allows the residual pollutant loads to be routed to option 5 without passing through the other parallel options. For example, street sweeping does not reach the entire surface pollutant load of an area. Therefore, some portion may be washed off by runoff events and routed to a storage-treatment facility without having the opportunity to be removed by sweeping. The influent to option 5 is the pollutant load not removed by the parallel group. This network will serve as an example and reference throughout the remainder of this section.

Once the production functions are established, the first step is to construct the total cost curve for each option (see Step 1, Figure 3). Production functions for several specific pollution control technologies and methods to develop the total cost curves are discussed in Section VI. However, for the purposes of generalization, a total cost curve is defined as a function of the fraction of pollutant removed, i.e.,

$$Z_p = CF_p(Y_p) \qquad (4)$$

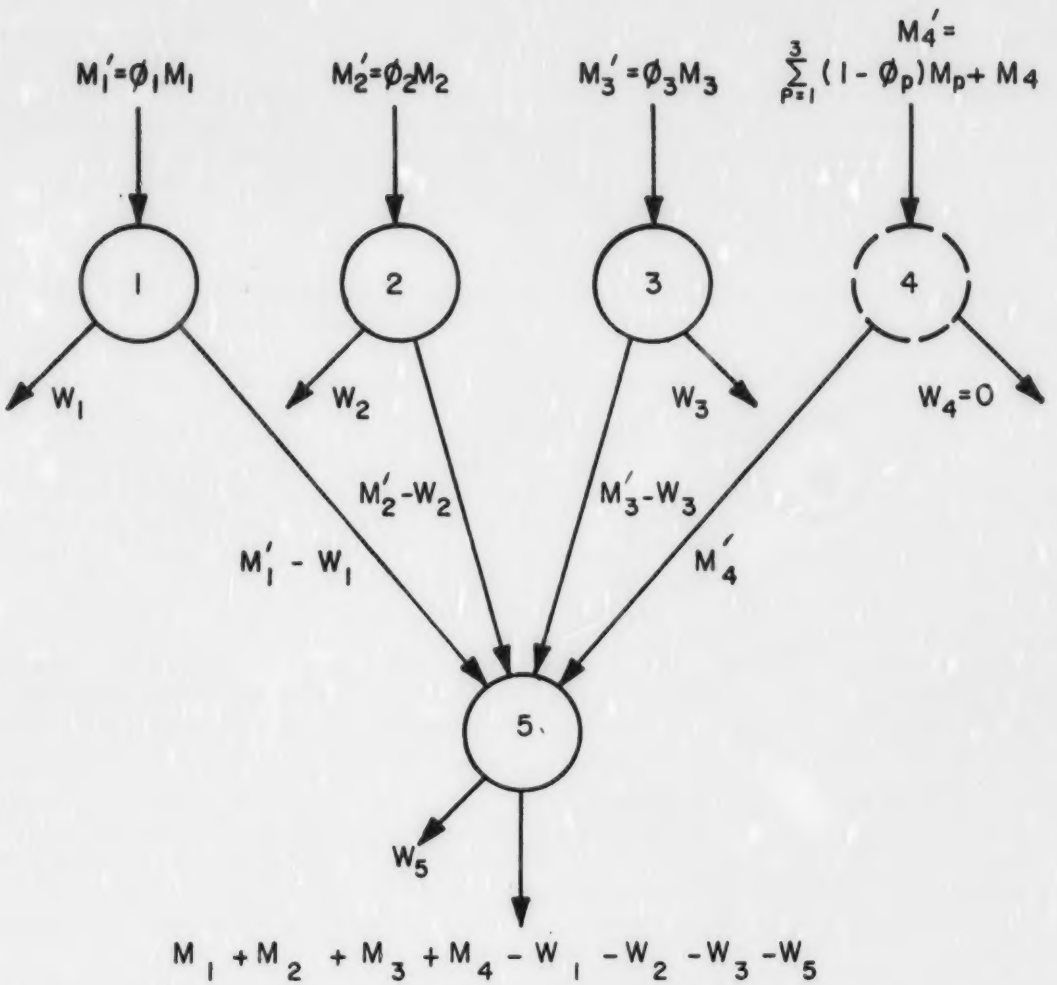
where Z_p = total cost for option p, \$/yr;

Y_p = fraction of available pollutant load removed by option p ($0 \leq Y_p \leq 1.0$); and

$CF_p(Y_p)$ = total cost function in terms of Y_p.

Recall that the fraction of available pollutant removed is the dependent variable of the production function. Thus, to derive the total cost curve, one only needs to reverse the axes of the production function and develop the relationship between the level of effort for option p, and the total cost. Mathematically, this may be stated as

$$X_p = PF_p^{-1}(Y_p) \qquad (5)$$



LEGEND

p = CONTROL PROCESS

M_p' = AVAILABLE POLLUTANT LOAD, lb/yr

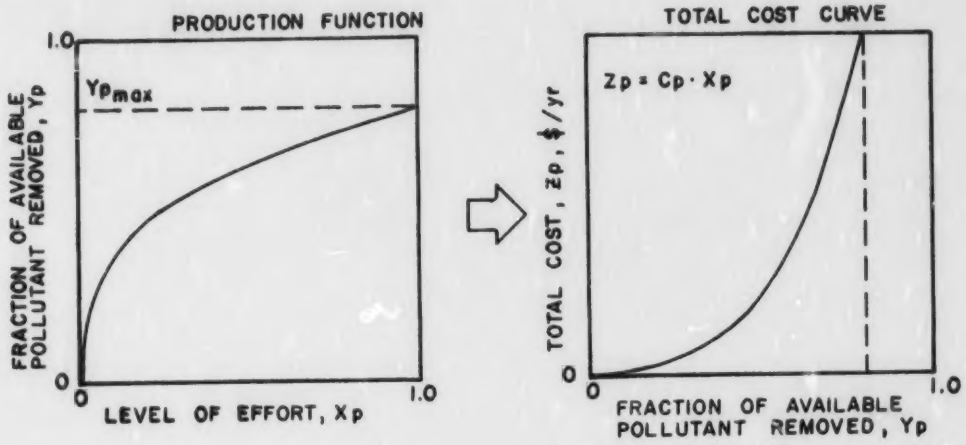
ϕ_p = AVAILABILITY FACTOR

M_p = POLLUTANT LOAD, lb/yr

W_p = POLLUTANT REMOVAL, lb/yr

Figure 2. Generalized Stormwater Pollution Control Network

STEP 1 : FIND TOTAL COST CURVE FOR EACH OPTION (p=1,2,3,4,and 5)



STEP 2 : FIND MARGINAL COST CURVE FOR EACH PARALLEL OPTION (p= 1,2,3, and 4)

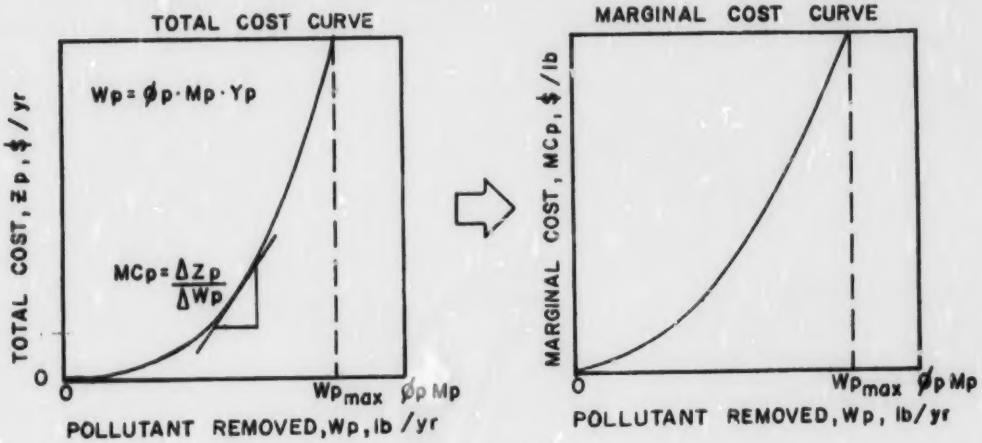


Figure 3. Graphical Procedure for Determining Optimal Control Strategies, Steps 1 and 2

where X_p = level of effort for option p ($0 \leq X_p \leq 1.0$);

Y_p = fraction of available pollutant load removed by option p ($0 \leq Y_p \leq 1.0$); and

$PF_p^{-1}(Y_p)$ = inverse of the production function for option p.

If total cost is assumed to be a linear function of the level of effort, then

$$Z_p = C_p \cdot X_p \tag{6}$$

where C_p = annual cost of option p per unit of effort, $\$/X_p$.

Substituting equation (5) into equation (6) yields

$$Z_p = C_p \cdot PF_p^{-1}(Y_p). \tag{7}$$

Equation (7) is the desired form of the total cost function (equation 4).

The next step is to generate the marginal cost curve for each parallel option (see Step 2, Figure 3). This curve gives the relationship between the marginal cost per pound of pollutant removed at any level of pollutant removed. The marginal cost curve is the first derivative of the total cost curve. However, the total cost curves for the parallel options must be converted from the fraction of pollutant removed to pounds removed. This is accomplished using the following equation,

$$W_p = M_p' \cdot Y_p \tag{8}$$

where W_p = pollutant removal by option p, lb/yr;

M_p' = pollutant load available to option p, lb/yr; and

Y_p = fraction of available pollutant load removed by option p ($0 \leq Y_p \leq 1.0$).

The maximum value of W_p, $W_{p_{max}}$, depends on the maximum removal efficiency of option p, $Y_{p_{max}}$. The equation used to find M_p' is

$$M_p' = \phi_p \cdot M_p \tag{9}$$

where ϕ_p = fraction of pollutant load (M_p) available to option p ($0 \leq \phi_p \leq 1.$); and

M_p = pollutant load in area served by option p, lb/yr, and $M_p = m_p \cdot A_p$;

where m_p = unit pollutant load in area served by option p, lb/ac-yr; and

A_p = area contributing pollutants to option p, ac.

The pollutant load per acre, m_p, can be found using methods described in Appendix A. The normalized version of the total cost curve (equation 4) may now be written as

$$Z_p = CF_p(W_p) \tag{10}$$

since only the units of the abscissa of the total cost curve are being changed. Utilizing equation (10), the marginal cost curve is described by the following equation,

$$MC_p = \frac{d(CF_p(W_p))}{dW_p} = MF_p(W_p) \tag{11}$$

where MC_p = marginal cost per pound of pollutant removed by parallel option p, \$/lb; and

$MF_p(W_p)$ = the marginal cost function in terms of W_p.

Graphically, the marginal cost curve is determined by finding the slope, $\Delta Z_p/\Delta W_p$, of the total cost curve at several values of W_p. These values, plotted against the values of W_p, give an approximation of the marginal cost curve. The marginal cost curves are increasing functions of pounds of pollutant removed. This result necessarily follows from the earlier assumptions of a concave production function and constant unit costs.

Once the marginal cost curves are developed for the parallel options, a composite marginal cost curve may be constructed (see Step 3, Figure 4). This single curve summarizes the effect of the entire parallel group (p = 1, 2, 3, and 4). This is accomplished by adding the marginal cost curves with respect to the ordinate of the marginal cost curves. In other words, at several equivalent values of MC_p for the parallel options, the corresponding W_p's are summed. The composite marginal cost curve is

$$MC_{II} = MF_{II}(W_{II}) \tag{12}$$

where MC_{II} = composite marginal cost per pound of pollutant removed by the parallel options, \$/lb;

W_{II} = pollutant removal by the parallel options, lb/yr, (= $W_1 + W_2 + W_3$, in the example network); and

$MF_{II}(W_{II})$ = the composite marginal cost function in terms of W_{II}.

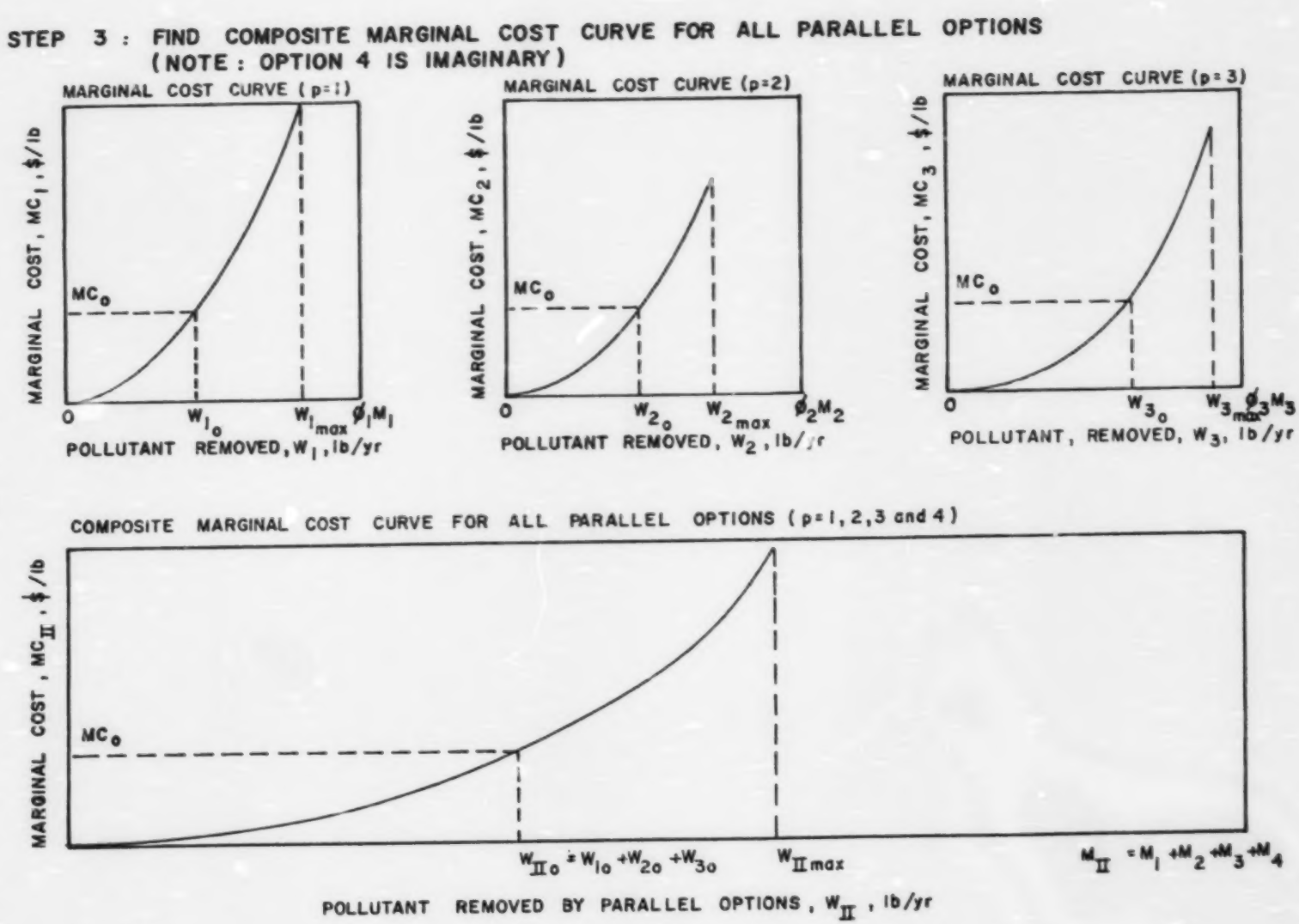


Figure 4. Graphical Procedure for Determining Optimal Control Strategies, Step 3

The composite total cost curve for the parallel options is constructed by integrating the composite marginal cost curve (see Step 4, Figure 5), i.e.,

$$Z_{II} = \int_{0}^{W_{II_{max}}} MF_{II}(W_{II})dW_{II} \qquad (13)$$

where Z_{II} = composite total cost of the parallel options, \$/yr; and

$W_{II_{max}}$ = maximum pollutant removal by the parallel options ($W_{1_{max}} + W_{2_{max}} + W_{3_{max}}$ in the example network), lb/yr.

At this point the economic behavior of the parallel group has been condensed into a single equivalent "option." Therefore, the problem has been reduced to one with two options in series. Next, the two-option serial operation is aggregated into a single equivalent "option" representing the entire example network. Although the procedure will be unique to a two-option serial operation, this will not limit the number of options in series that may be analyzed. Any number of options may be aggregated by simply working with pairs until condensed to one equivalent "option." The previous procedure for the parallel case may be applied to any number of options.

A two-option serial operation may be viewed as a production "process" with two inputs and one output. The production function can be described using isoquants (see Figure 1), i.e., lines of input combinations capable of producing a constant output and having the following characteristics [12]:

(1) Isoquants cannot intersect. Intersection would imply that the same input levels are capable of producing different output levels.

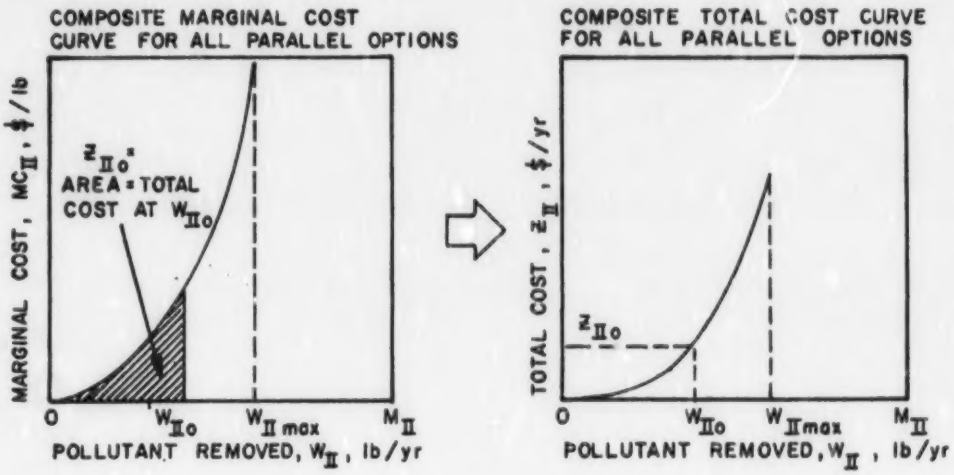
(2) Isoquants slope downward to the right because increased use of one input requires the lessened use of the other input.

(3) Isoquants are convex to the origin due to the inability of one input to be substituted for another at a specific level of output.

The inputs are the total costs of each option in series and the output is the fraction of pollutant removed by the serial operation. In this particular case, the inputs are the composite total costs for the parallel group, Z_{II}, and the total costs for the subsequent option, Z_5.

Before constructing the isoquants of the fraction removed by the serial operation, both total cost curves must be in terms of the fraction of pollutant removed. The curve for option 5 was constructed earlier (see

STEP 4 : INTEGRATE COMPOSITE MARGINAL COST CURVE TO OBTAIN COMPOSITE TOTAL COST CURVE FOR ALL PARALLEL OPTIONS



STEP 5 : FIND ISOQUANTS OF THE FRACTION OF POLLUTANT REMOVED BY OPTIONS IN SERIES, Y_{ω}

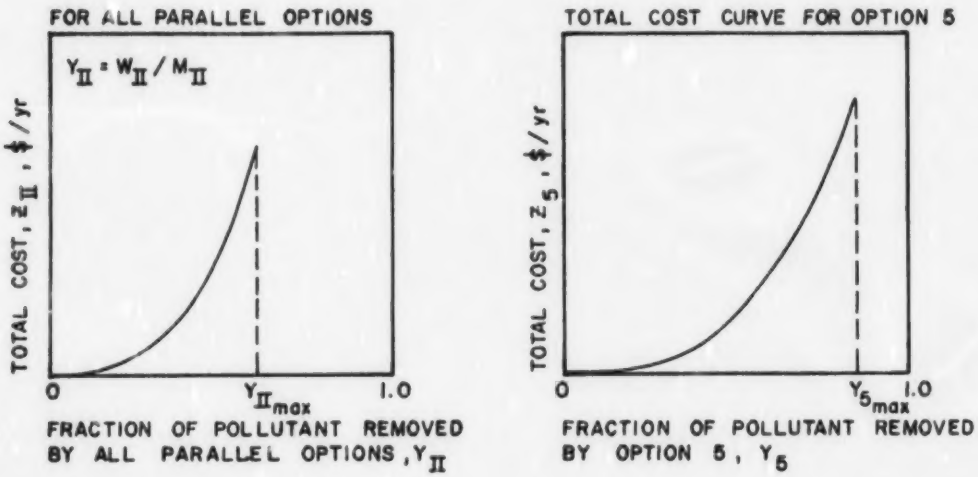


Figure 5. Graphical Procedure for Determining Optimal Control Strategies, Steps 4 and 5

Step 1, Figure 3) and is already in the proper form. The composite total cost curve for the parallel group was left in terms of the pounds of pollutant removed (equation 13). The following equation is used to convert to the fraction removed:

$$Y_{II} = W_{II}/M_{II} \tag{14}$$

where M_{II} = pollutant load available to all parallel processes ($= M_1 + M_2 + M_3 + M_4$), lb/yr.

These curves must be in terms of the fraction removed due to the nature of the serial operation. Essentially, one input is passing through two options, as opposed to a parallel operation where each input is independent. Therefore, the action of one affects the other and it becomes necessary to optimize the fraction removed by each option and then determine what quantity of pollutant was removed by each, rather than the reverse.

Constructing the isoquants of the overall fraction of pollutant removed requires several combinations of Y_{II} and Y_5 capable of providing the desired overall fraction. This is determined by the following equation,

$$Y_\psi = Y_{II} + Y_5(1-Y_{II}) \tag{15}$$

where Y_ψ = fraction of pollutant removed by the serial operation.

Equation (15) states that the fraction of pollutants removed by the serial operation is the sum of the removal from the first option, Y_{II}, and the incremental removal due to the second option, $Y_5(1-Y_{II})$. By noting the Z_{II} and Z_5 corresponding to the various combinations of Y_{II} and Y_5 from each of the total cost curves, the isoquants may be drawn (see Step 5, Figures 5 and 6).

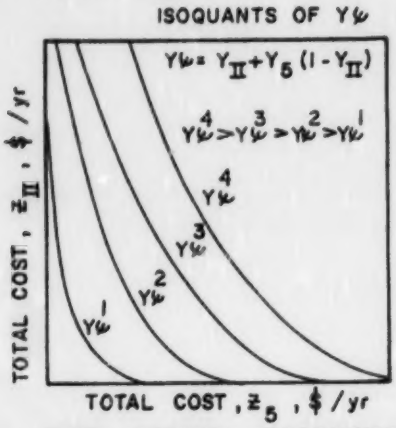
The next step is to develop the optimal expansion path from the isoquants by constructing points of tangency between the isoquants and isocost lines. As the name suggests, isocost lines are lines of equal cost. The isocost lines are given as

$$Z_\psi = Z_{II} + Z_5 \tag{16}$$

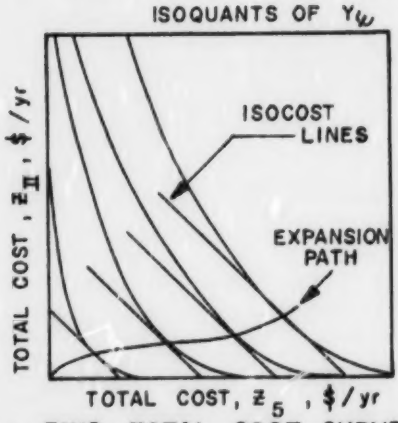
where Z_ψ = composite total cost of the serial operation, $/yr.

The slope of this linear equation is -1. Therefore, to find the point of tangency simply requires that the point on the isoquant tangent to a line of a negative unit slope be located. These points determine the optimal or least-cost combination of costs from each option. The optimal solution may fall at a corner point. Connecting these points gives the optimal expansion path (see Step 6, Figure 6). The final step is to construct a composite total cost curve for the serial operation. This may be done by plotting the values of Z_ψ against the corresponding values of Y_ψ found on the optimal expansion path (see Step 7, Figure 6). This curve, for the

STEP 5 : (CONTINUED)



STEP 6 : FIND OPTIMAL EXPANSION PATH



STEP 7 : FIND TOTAL COST CURVE FOR ALL OPTIONS (p = 1,2,3,4, and 5)

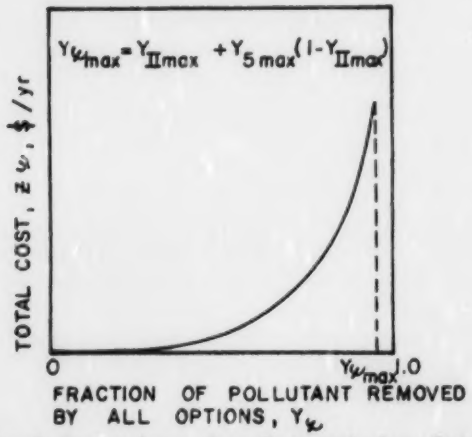


Figure 6. Graphical Procedure for Determining Optimal Control Strategies, Steps 5 (concluded), 6 and 7

example network shown in Figure 2, represents the final total cost for the entire network as a function of the overall fraction of pollutant removed. If there were subsequent options the curve would merely represent a composite of two options in series that could next be combined with the following process.

The methodology for establishing optimal strategies has been developed. At this point, a planner could select an overall removal fraction and proceed, in reverse, through the seven steps shown in Figures 3 through 6 and determine the optimal operating levels of each option. This is demonstrated by the example application found in Section VII.

SECTION VI

CONTROL TECHNOLOGIES

Section V set up a methodology by which engineers and planners could determine an optimal strategy with any number of control options. For the purposes of this study, four technologies will be considered: street sweeping, combined sewer flushing, catch-basin cleaning, and storage-treatment. Typically, these technologies operate as shown in Figure 7. Only combined sewered areas may utilize all four technologies. Storm sewered areas do not require sewer flushing to remove sanitary sewage deposition. In addition to flushing, unsewered areas do not have catch basins or street sweeping since materials are transported to adjacent pervious areas. (It is assumed that there are no gutters.) For combined sewered areas the network operates in the following manner. A portion of the street solids are removed by sweeping and a portion are washed off during runoff events and partially captured by catch basins which are subsequently cleaned by artificial means or flushed by a storm surge. The sanitary sewage deposited in the sewer lines is also flushed artificially or by storm surges. The pollutants flushed from the catch basins and sewer lines during storm surges are sent to the wet-weather storage-treatment facility. The material removed from the catch basins is normally sent to a sanitary landfill. The material flushed from the sewers is sent to the dry-weather treatment plant.

This section develops the production function for each technology. Additionally, the relationships to construct the total cost curves are given. With this information, the methodology of Section III may be applied to any urbanized area.

The term "pollutant" has been used almost exclusively up to this point. However, the pollutant BOD will be the parameter of concern in this and remaining sections. BOD is the most commonly used indicator of general water pollution levels. The same method could be used for any other single pollutant.

STREET SWEEPING

The sweeping of roadways is a long-established practice in American cities. However, the primary purpose of this activity is the removal of unsightly debris. Recent studies indicate that a portion of the material found on the streets (and therefore a potential pollution source during runoff events) may be removed by a conscientious sweeping program [4, 5]. The particle size and pollutant distribution of street contaminants are shown

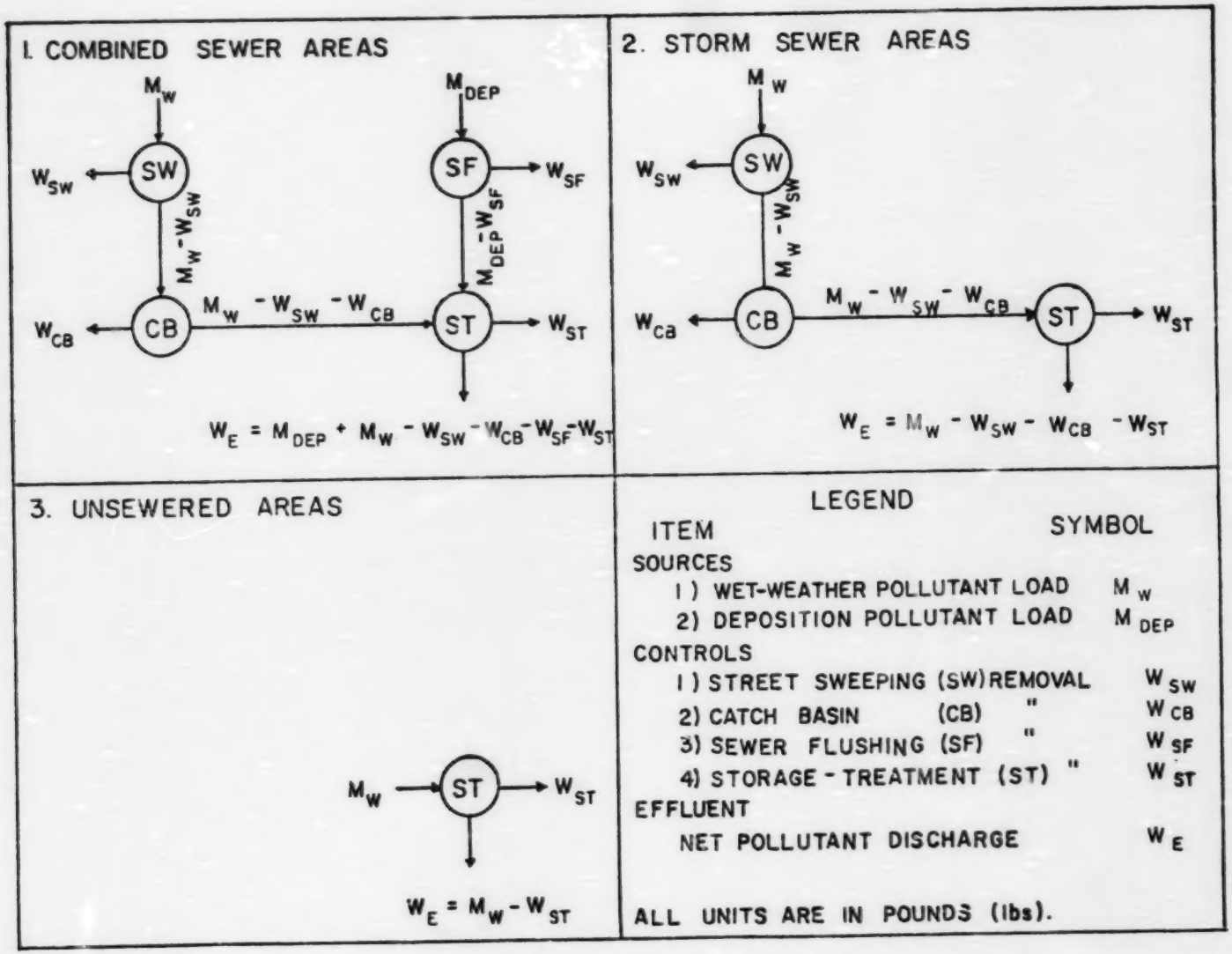


Figure 7. Stormwater Pollution Control Technologies - Availability Factors Equal 1.0

in Table 4.

Street sweeping may be performed manually or mechanically, with the latter enjoying more widespread usage. Mechanical sweepers are divided into two categories: brush-type and vacuum-type. Removal efficiencies with brush-type sweepers for various particle sizes are shown in Table 5. The overall efficiency is 0.50 with the coarser materials enjoying higher efficiencies than fine particles. APWA reports that vacuum type sweepers have achieved efficiencies of greater than 0.95 [5]. Of course, the increased efficiency of vacuum sweepers results in a substantially higher cost over brush-types.

Street sweeping has several advantages and disadvantages as a pollution control technique. Some favorable characteristics are the

(1) control of pollutants at the source; and

(2) dual purpose of sweeping for pollution control and esthetics.

Unfavorable traits include

(1) relatively low efficiency as a pollution control measure;

(2) sweeper's history as a traffic hazard;

(3) removal of only the portion of the load located near the gutter; and

(4) problems of vehicular parking along the streets.

Although sweeping has a relatively low removal efficiency, in a coordinated system of storage-treatment and other management practices, it may prove to be a viable alternative.

Street sweeping may be considered a production process (as described earlier). Indeed, all pollution control techniques may be described as such. Therefore, it is possible to describe the technological relationship between the input and output of street sweeping in terms of a production function. In this case, the input is the fraction of the days on which sweeping occurs during a year and the output is the fraction of BOD removed.

In order to generate the production function a model was developed to simulate the conditions within an urbanized area and the effect of street sweeping. Hourly rainfall is converted to runoff using a simple runoff coefficient, and subsequently accumulated BOD is removed by scheduled sweeping or a runoff event. The model makes use of the following assumptions:

(1) The average removal efficiency for BOD is equivalent to that of all particle sizes. This is assumed because of the apparent consistency of the portion of BOD

TABLE 4. PERCENT OF STREET POLLUTANTS IN VARIOUS PARTICLE SIZE RANGES

Pollutant	Percent of Pollutant Associated with Each Particle Size Range (microns)					
	>2,000	840 → 2,000	246 → 840	104 → 246	43 → 104	< 43
Total Solids	24.4	7.6	24.6	27.8	9.7	5.9
Volatile Solids	11.0	17.4	12.0	16.1	17.9	25.6
BOD_5	7.4	20.1	15.7	15.2	17.3	24.3
COD	2.4	4.5	13.0	12.4	45.0	22.7
Kjeldahl Nitrogen	9.9	11.6	20.0	20.2	19.6	18.7
Nitrates	8.6	6.5	7.9	16.7	28.4	31.9
Phosphates	0	0.9	6.9	6.4	29.6	56.2

Source: Sartor, J.D., and Boyd, G.B., "Water Pollution Aspects of Street Surface Contaminants," USEPA Report EPA-22-72-081, November 1972, p. 7.

TABLE 5. BRUSH-TYPE SWEEPER EFFICIENCY FOR VARIOUS PARTICLE SIZE RANGES

Particle Size (microns)	Sweeper Efficiency (%)
2000	79
840→2000	66
246→ 840	60
104→ 246	48
43→ 104	20
<43	15
Overall	50

Source: Sartor, J.D., and Boyd, G. B., "Water Pollution Aspects of Street Surface Contaminants," USEPA Report EPA-22-72-081, November 1972, p. 10.

contained within the particle size ranges (see Table 4).

(2) A runoff event encompasses consecutive hourly runoff occurrences and intermittent dry periods not to exceed twelve hours. For example, an intermittent dry period of twelve hours will start a new event; a period of eleven hours or less will not [1].

(3) No sweeping occurs during an event. If an event and a scheduled sweeping coincide the streets are simply not swept until the next scheduled time.

(4) Only one pass is made per sweep.

The pollutant washoff functions incorporated in the model were identical to the functions found in the SWMM and STORM models [13, 14]. However, the methods of pollutant build-up and removal by street sweeping are somewhat different. SWMM and STORM allow the linear build-up of pollutants as long as the elapsed time from the previous runoff event is less than the street sweeping interval. The relationship is

$$P_1 = F \cdot DD \cdot N_D + P_o \tag{17}$$

where P_1 = total pollutant load at the beginning of the storm, lb;

F = pounds of pollutant per pound of dust and dirt;

DD = daily dust and dirt accumulation rate, lb/day;

N_D = number of dry days since the last storm; and

P_o = pounds of pollutant remaining at the end of the last storm (event).

If the number of days since the last runoff event is greater than the sweeping interval, the following equation is employed by SWMM and STORM.

$$P_1 = P_o(1-\varepsilon)^n + N_S \cdot DD \cdot F \cdot [(1-\varepsilon)^n + (1-\varepsilon)^{n-1} + \ldots + (1-\varepsilon)] \tag{18}$$

$$+ DD \cdot F \cdot (N_D - nN_S)$$

where N_S = number of days between street sweepings;

n = number of times the streets were swept since the last storm; and

ε = "pick up" efficiency of the street sweeping equipment.

The major flaw in this procedure is that the street sweeping "counter" is set to zero at the end of every runoff event. In other words, after the end of an event, N_s days must pass before sweeping occurs. Therefore, it is conceivable that the streets will never be swept according to this procedure. For example, assume that N_s is 20 days. If the longest dry period during a year is 15 days, STORM and SWMM will fail to simulate any sweeping--even though an interval of 20 days was specified.

To correct this deficiency, the model developed for this study merely establishes a sweeping schedule from which no deviation is allowed except in the case of a coincident runoff event. This is not an entirely accurate assumption, for public works departments certainly have the flexibility to alter their sweeping schedule. However, this is not considered to be a serious error. When sweeping does occur, the amount of pollutant removed is taken as the product of the accumulated pollutants available and the "pick-up" efficiency.

Not all of the accumulated pollutants are available for removal by sweeping. There are considerable amounts on parking lots, driveways, and other impervious areas not subject to sweeping by municipal units. Total and street imperviousness as a function of developed population density is shown in Figure 8 [1]. If pollutants are assumed to be uniformly distributed over the impervious area and that only the pollutants in the street are sweepable, then

$$\phi_{SW} = \frac{I_s}{I} \approx 0.6\ PD_d^{-0.2} \quad \text{for } PD_d \geq 0.1 \qquad (19)$$

where ϕ_{SW} = sweeping availability factor, i.e., proportion of pollutant load which is sweepable ($0 \leq \phi_{SW} \leq 1.0$);

I_s = imperviousness due to streets only, percent; and

I = total imperviousness, percent.

A plot of equation (19) (Figure 9) shows that ϕ_{SW} ranges from about 0.43 at PD_d = 5 persons/ac (12.4 persons/ha) to about .35 at PD_d = 15 persons/ac (37.1 persons/ha). In actuality, a disproportionate amount of the pollution is located on the streets or is delivered to the streets prior to entering the final drainage canals. To test the sensitivity of the result to ϕ_{SW}, evaluations will be made with ϕ_{SW} = 0.40 representing a lower bound ϕ_{SW} = 1.0 representing the upper bound, and ϕ_{SW}=0.70 representing an average value.

Running the model with several different efficiencies (ranging from 0.1 to 0.9) and sweeping intervals (ranging from 1 to 42 days) generated the family of production functions shown in Figure 10. The model was run using data for the developed areas of Minneapolis, Minnesota (including hourly precipitation for 1971). The production function for a "pick-up" efficiency of 0.50 is used to describe the typical mechanical sweeping operation. This corresponds to the efficiency shown in Table 5 for brush-type sweepers. The efficiency could be any value suitable to local conditions. For

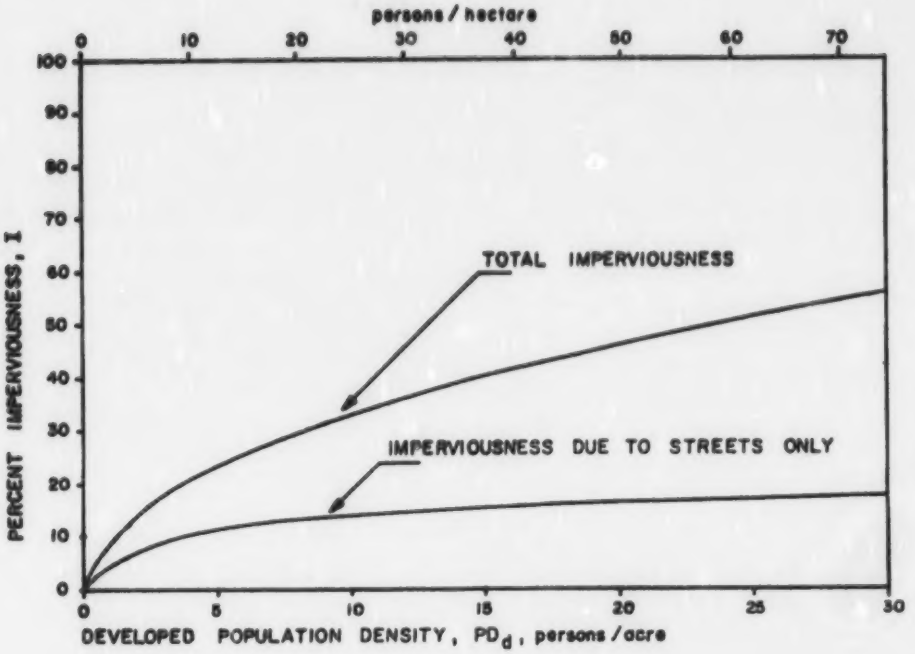


Figure 8. Imperviousness as a Function of Developed Population Density

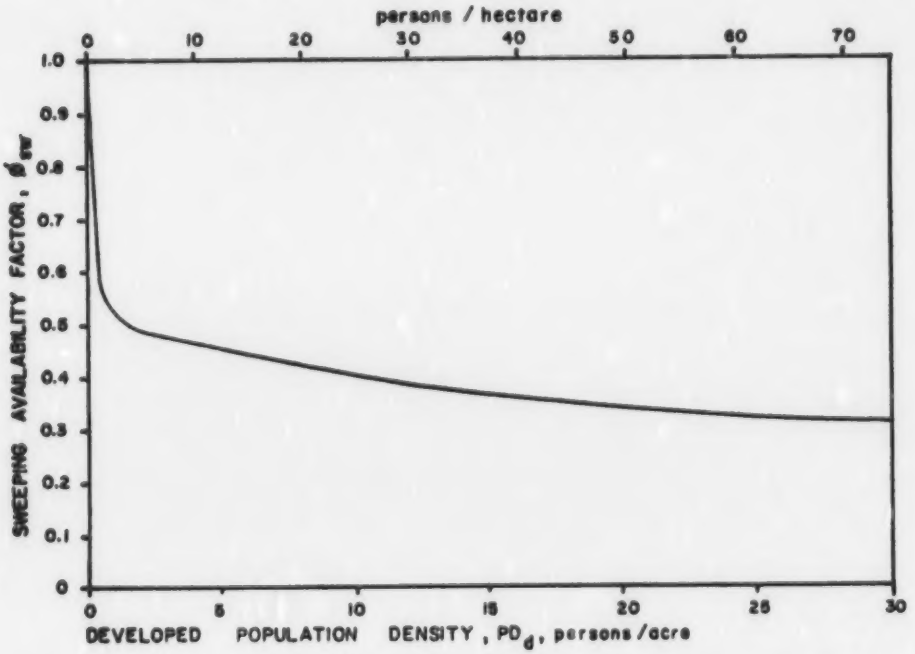


Figure 9. Sweeping Availability Factor as a Function of Developed Population Density

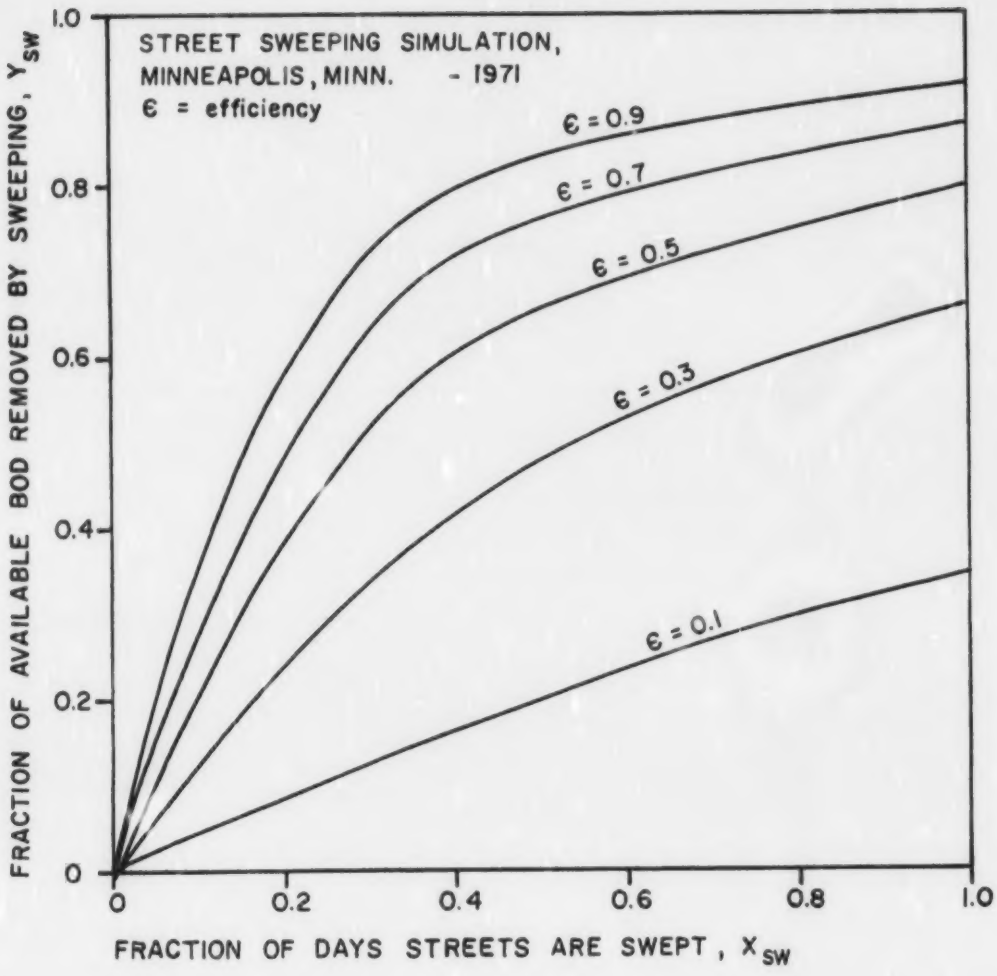


Figure 10. Production Functions for Street Sweeping

example, the use of vacuum sweepers would dictate the use of a higher efficiency.

The production function generated by the model is in terms of the fraction of BOD removed annually. In order to generate the total cost curve the fraction removed must be converted to the pounds of BOD removed (as described in Section V). Therefore,

$$W_{SW} = (m_W - m_{DEP}) \cdot A_{SW} \cdot \phi_{SW} \cdot Y_{SW} \quad (20)$$

where W_{SW} = wet-weather BOD removed by sweeping, lb/yr;

m_W = annual wet-weather BOD load, lb/ac-yr;

m_{DEP} = annual wet-weather BOD load due to combined sewer deposition, lb/ac-yr;

A_{SW} = area to be swept, ac;

ϕ_{SW} = sweeping availability factor, i.e., proportion of BOD load which is sweepable ($0 \leq \phi_{SW} \leq 1.0$); and

Y_{SW} = fraction of available BOD removed by sweeping ($0 \leq Y_{SW} \leq 1.0$).

The unit pollutant loads, m_W and m_{DEP} may be found using methods described in Appendix A.

Assuming that the total annual cost of sweeping, Z_{SW}, is a linear function of the number of sweepings, the total cost curve for any urbanized area (or subarea) is given by the following equation,

$$Z_{SW} = 365 \cdot C_{SW} \cdot G \cdot A_{SW} \cdot X_{SW} \quad (21)$$

where C_{SW} = cost per curb mile swept, $/curb-mile;

G = gutter length in A_{SW}, curb-miles/ac;

X_{SW} = fraction of days per year the area is swept ($0 \leq X_{SW} \leq 1.0$); and

$X_{SW} = PF_{SW}^{-1}(W_{SW})$, the inverse production function of street sweeping expressed in terms of W_{SW}.

The value for gutter length, G, may be estimated by an equation developed by Graham *et al.* [15],

$$G = 0.0782 - 0.0668(.839)^{PD_d} \quad (22)$$

where PD_d = population density for developed areas, persons/ac.

Also, some average values for gutter length are shown in Table 6. The sweeping cost per curb mile, C_S, is more difficult to determine. APWA reports a wide range of values for several street sweeping cost parameters from over 160 municipalities [16]. The median and mean for each parameter are given in Table 7. The median value of $7.00/curb mile ($4.35/curb-km) swept will be used because of the large variance in the data.

COMBINED SEWER FLUSHING

Combined sewers often experience dry-weather sewage deposition. These solids accumulate in the sewers until removed by a storm surge or by artificial flushing. The deposition carried away by runoff discharges directly to the receiving water if the dry-weather treatment plant is bypassed. Controlled flushing allows the sewers to be cleaned without adding pollutants to the water body. Instead, these pollutants are routed to the dry-weather plant for treatment.

As with street sweeping, sewer flushing is not a new idea; its primary purpose has been to improve hydraulic capacity and self-scouring ability. However, several reports indicate the ability of a flushing program to remove a substantial portion of the pollutants associated with deposition [2, 3, 6]. Several systems are available for sewer flushing, e.g., flushing stations, in-line storage, and portable tankers. Flushing stations are tanks placed at strategic locations that release the required flushing volumes. Varying degrees of automation are utilized [3]. In-line storage involves a system of internal dams used to block the sewage flow at upstream points for rapid release to scour downstream elements [2]. The use of tankers merely requires that the trucks be dispatched to the system components requiring flushing.

Pisano has investigated the deposition problem in two Boston systems--Dorchester and South Boston [2]. The two systems have a total of 2666 sewer elements with an average length between manholes of 191 ft (58.2m) per segment. Through a simulation model it was estimated that 10.3 percent of the daily dry-weather solids in the Dorchester system was deposited in the lines. The South Boston system retained 6.6 percent. Also, the Dorchester system retains 75 percent of the total deposition in only 18 percent of the system components. South Boston retains 63 percent in 22 percent of the components. Therefore, a relatively small portion of the combined sewer elements retain a substantial amount of the total deposition. As expected, pipe slope was reported to be the major factor in determining potential deposition problems.

Pisano provided the data used to develop the sewer flushing production function [2]. The input to this process is the fraction of the combined sewer segments flushed daily. The output is the fraction of available BOD removed annually by flushing. The production function is based on information regarding the relative concentration of deposition within the two systems of Boston (e.g., 75 percent of the deposition is found in 18 percent of the Dorchester system elements). The function, shown in Figure 11,

TABLE 6. AVERAGE VALUES OF GUTTER LENGTH

Land Use	Curb or Gutter Length	
	miles/ac (km/ha)	ft/ac (m/ha)
Residential	0.059 (0.235)	312 (235)
Commercial	0.070 (0.279)	370 (279)
Industrial	0.034 (0.136)	180 (136)
Other	0.023 (0.091)	121 (91)

Source: Heaney, J.P., Huber, W.C., Medina, M.A., Murphy, M.P., Nix, S.J., and Hasan, S.M., "Nationwide Evaluation of Combined Sewer Overflows and Urban Stormwater Discharges, Volume II: Cost Assessment," USEPA Report EPA-600/2-77-064B, March 1977.

TABLE 7. UNIT COSTS OF STREET SWEEPING

	Street Sweeping Costs			
	$/curb-mile ($/curb-km)	$/yd^3 ($/m^3)	$/ton ($/metric ton)	$/capita/year
Mean	86.61 (53.82)	22.14 (28.96)	31.31 (34.51)	1.54
Median	7.00 (4.35)	13.79 (18.04)	14.28 (15.74)	1.23

Source: Unpublished data from American Public Works Association, 1976.

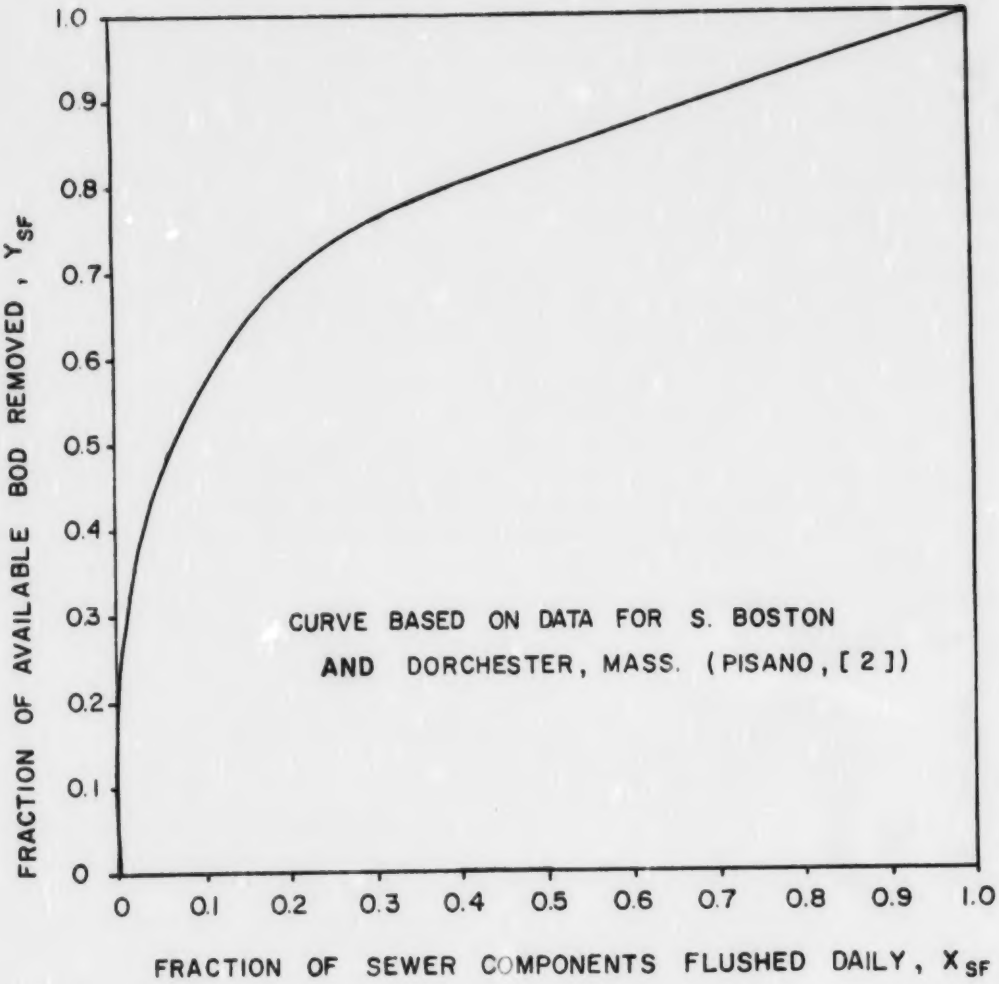


Figure 11. Production Function for Combined Sewer Flushing

is based on several assumptions:

(1) A flushing program cleanses a designated portion of the system elements daily.

(2) Daily flushing will remove virtually 100 percent of the available daily deposition. This assumes that the sewers have been properly maintained and do not contain beds of debris. Of course, not all of the annual deposition will be available for flushing, i.e., some portion will be removed by runoff events.

(3) Pisano reports deposition in terms of suspended solids. BOD, the pollutant of concern here, is assumed to be deposited in a similar manner [2].

(4) All components or pipe sections are ranked, according to the severity of the deposition problem, for flushing priority.

(5) The BOD flushed daily is routed to the dry-weather treatment facility. The flushing volumes are small enough to prevent an artificial combined sewer overflow.

Inspection of the production function reveals that sewer flushing also exhibits decreasing marginal output as the input is increased. In fact, the effect is dramatic after approximately 10 or 20 percent of the sewers are flushed daily.

To develop a total cost function for any urbanized area, it is necessary to convert the production function in terms of the fraction of BOD removed to the pounds of BOD removed annually. This is accomplished by the following equation,

$$W_{SF} = \phi_{SF} \cdot m_{DEP} \cdot A_{SF} \cdot Y_{SF} \qquad (23)$$

where W_{SF} = BOD in deposition removed by daily sewer flushing, lb/yr;

ϕ_{SF} = sewer flushing availability factor, i.e., proportion of pollutant load that is flushable ($0 \leq \phi_{SF} \leq 1.0$);

m_{DEP} = annual BOD load of combined sewer deposition, lb/ac-yr;

A_{SF} = area served by combined sewers to be flushed, ac; and

Y_{SF} = fraction of available BOD removed by flushing ($0 \leq Y_{SF} \leq 1.0$).

A method of estimating the combined sewer deposition BOD load, m_{DEP}, is found in Appendix A. A more refined procedure is being developed. Results should be available later this year [17].

Assuming that the total annual costs of sewer flushing, Z_{SF}, are a linear function of the system footage to be flushed, the total cost curve for any area is given by the following equation,

$$Z_{SF} = C_{SF} \cdot (0.40G) \cdot A_{SF} \cdot X_{SF} \qquad (24)$$

where C_{SF} = cost per mile of sewer flushed, $/mile;

$0.40G$ = sewer length in A_{SF}, miles/ac = 40 percent of gutter length;

X_{SF} = fraction of combined sewerage system components flushed daily ($0 \leq X_{SF} \leq 1.0$); and

$X_{SF} = PF_{SF}^{-1}(W_{SF})$, the inverse sewer flushing production function in terms of pounds of BOD removed.

This equation and the construction of the total cost curve require several assumptions:

(1) Flushing will be performed by the in-line storage and sudden release of dry-weather flow at upstream locations [2].

(2) The redeposition of BOD at the trailing edge of the resulting flush wave is assumed to be negligible [2].

(3) The cost per unit length of flushed sewer line is constant; regardless of pipe size, type, slope, or Manning's n.

(4) The length of combined sewers per acre is assumed to be 40 percent of the gutter length. Equation 22 or Table 6 may be used to estimate the gutter length, G.

Pisano indicates that the total present worth of the cost (capital and operation/maintenance) per in-line flushing module (inflatable dam) and the initial cleaning is $22,500. It is assumed that one module is needed per segment requiring flushing. The annual cost per module is $2,250 (8% interest, 20 year service life). The Boston system segments have an average length of 191 feet. Therefore, the annual cost of flushing per unit length of sewer line is $11.78/ft ($38.64/m) or $62,200/mile ($38,600/km).

CATCH-BASIN CLEANING

In a study dealing with overall catch-basin performance, Metcalf and Eddy, Inc. define a catch basin as [18]:

> a chamber or well, usually built at the curb line of a street, for the admission of surface water to a sewer or subdrain, having at its base a sediment sump designed to retain grit and detritus below the point of overflow.

This definition implies that catch-basins are not intended to remove BOD or suspended solids, but act primarily as grit chambers designed to prevent the clogging of sewer lines. However, the catch basin does act as a sedimentation tank capable of removing some portion of the BOD. Unfortunately, the small portion of BOD removed may be flushed from the sump during runoff events. Catch basins act much as septic tanks, but are subject to highly variable and, often, overwhelming flows. Lager and Smith estimate the typical pollution control effectiveness in an example shown in Table 8 [18]. The efficiency of BOD removal, calculated below using data from Table 8, i.e.,

$$\text{Efficiency} = \frac{\text{removal - loss}}{\text{input}} = \frac{(345{,}800 - 262{,}500)\ 100}{25{,}000 \text{ basins } (50 \text{ storms})(1.04 \text{ lb})}$$

$$= 6.4\%$$

indicates that the expected removal level is not significant. For this reason, catch-basin cleaning will not be analyzed further.

STORAGE-TREATMENT

The remaining method of controlling stormwater pollution involves storage and/or treatment of the collected runoff. Storage-treatment facilities operate in series with the management practices.

A variety of storage and treatment technologies are available. Examples of storage include

(1) in-line storage,

(2) tanks,

(3) lagoons, and

(4) tunnels.

Treatment methods include

(1) sedimentation,

TABLE 8. EXAMPLE PROBLEM EVALUATING CATCH-BASIN PERFORMANCE

EXAMPLE PROBLEM 7-3: ANNUAL POLLUTION ASSESSMENT OF CATCHBASIN PERFORMANCE[Δ]

Given the conditions expressed in the preceding problems, determine the aggregate effectiveness of the catchbasins over a period of years in terms of BOD_5 removed.

Specified Conditions

1. Total number of catchbasins = 25,000.
2. Curb length per catch basin = 0.10 curb mile (0.16 curb-km).
3. Annual precipitation = 35.1 in (89.2 cm).
4. Catchbasins are cleaned twice a year.
5. The pollution load displaced from each basin is 0.21 lb (.10 kg) BOD_5 for each of 50 storms occurring in a year.
6. The runoff coefficient = 50%.

Assumptions

1. The annual rainfall can be characterized as 50 equal 5-h storms.
2. BOD_5 removal by sedimentation will total 26.6% of the applied load.

Solution

1. Determine the annual loss of BOD_5 by liquid volume displacement.

   BOD_5 loss = 25,000 basins x 50 storms x 0.21 lb (.10 kg)

   = 262,500 lb/yr (125,000 kg/yr)

2. Compute the BOD_5 entering a catchbasin each storm (following procedures of earlier example).

   BOD_5 entering = 1.3 lb (.59 kg) available x 0.80 removed from streets

   = 1.04 lb (.47 kg)

3. Determine the annual removal of BOD_5 by sedimentation.

   BOD_5 removed = 25,000 basins x 50 storms x [1.04 lb (.47 kg) x 0.266]

   = 345,800 lb/yr (156,800 kg/yr)

4. Compare the net benefit ratio

   Benefit = 345,800 lb (156,800 kg) removed ÷ 262,500 lb (119,000 kg) lost

   = 1.32:1.

Comment

The problem illustrates that from a pollution abatement standpoint the benefits of catchbasins are marginal at best. Of course, with the cleaning frequency of twice per year, the liquid fraction pollution might average half the specified value, thereby doubling the benefit ratio; however, the gross impact is still small. This example is based on grossly synthesized data and real, long-term removal data from a few catchbasins are required for an actual assessment of catchbasins.

[Δ]Reference: Lager, J.A., and Smith, W.G., "Catchbasin Technology Overview and Assessment," USEPA Report (draft), 1977.

(2) swirl concentrators,

(3) microstrainers,

(4) dissolved air flotation,

(5) contact stabilization, and

(6) physical-chemical treatment.

The operation of a storage-treatment facility is a production process involving two inputs and one output. The inputs are the storage capacity and the maximum treatment rate and represent the input vector to the storage-treatment process, $\underline{X}_{ST}$. The output is the fraction of available BOD removed annually, Y_{ST}.

A methodology to derive the production function and total cost curve for storage-treatment in any urbanized area is discussed in an EPA publication by Heaney, Huber, and Nix [7]. Rather than summarize this methodology here, the reader is referred to this report for details. With relatively little data, the production function and total cost curve may be derived for any city in the U.S. As an example, a production function (in the two-dimensional isoquant form) for Atlanta, Georgia, is shown in Figure 12. Additionally, a total cost curve for the storm sewered areas of that city is shown in Figure 13.

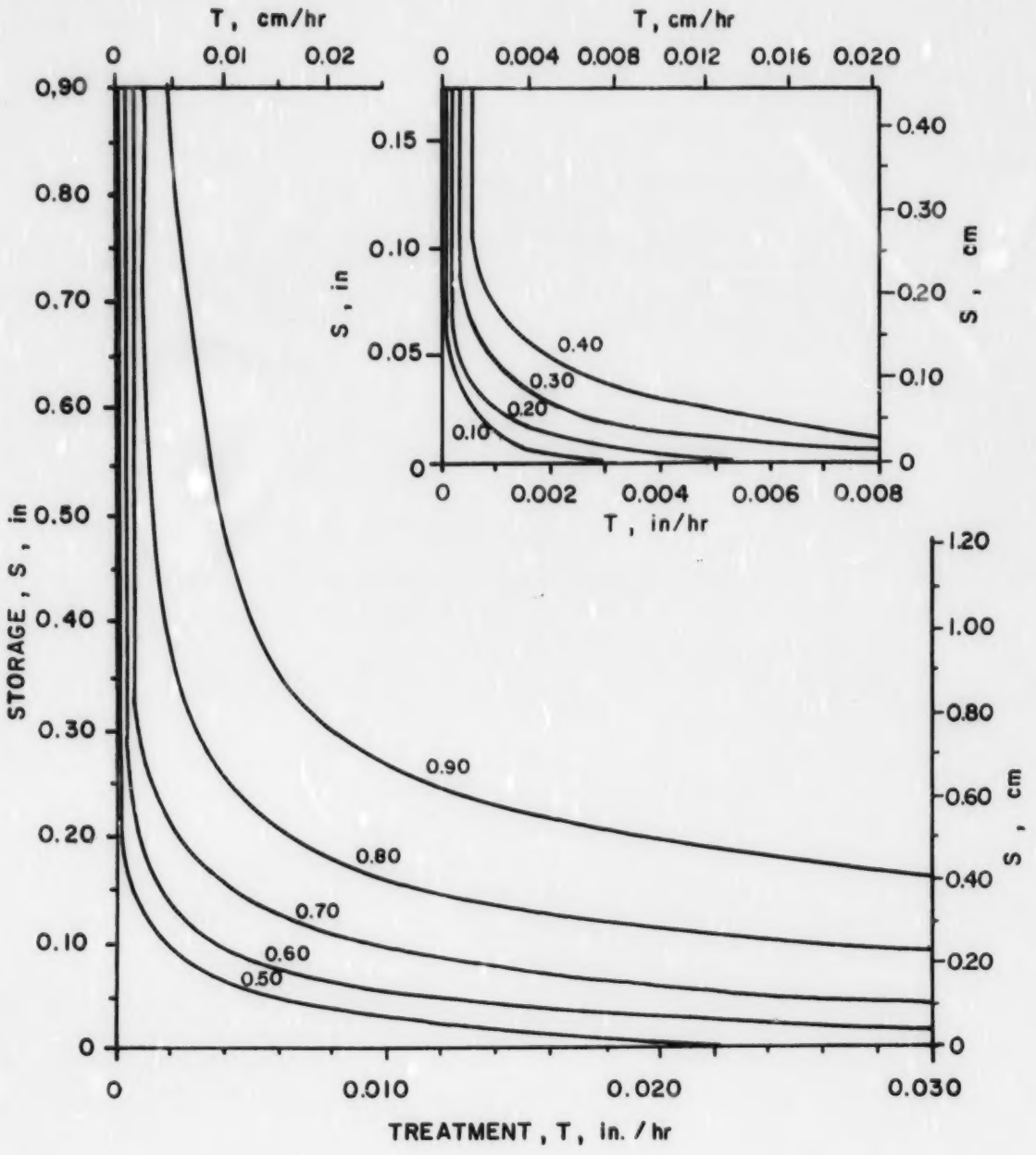


Figure 12. Production Function (Isoquants) for Storage-Treatment, Atlanta, Georgia [Heaney, Huber and Nix, 1976]

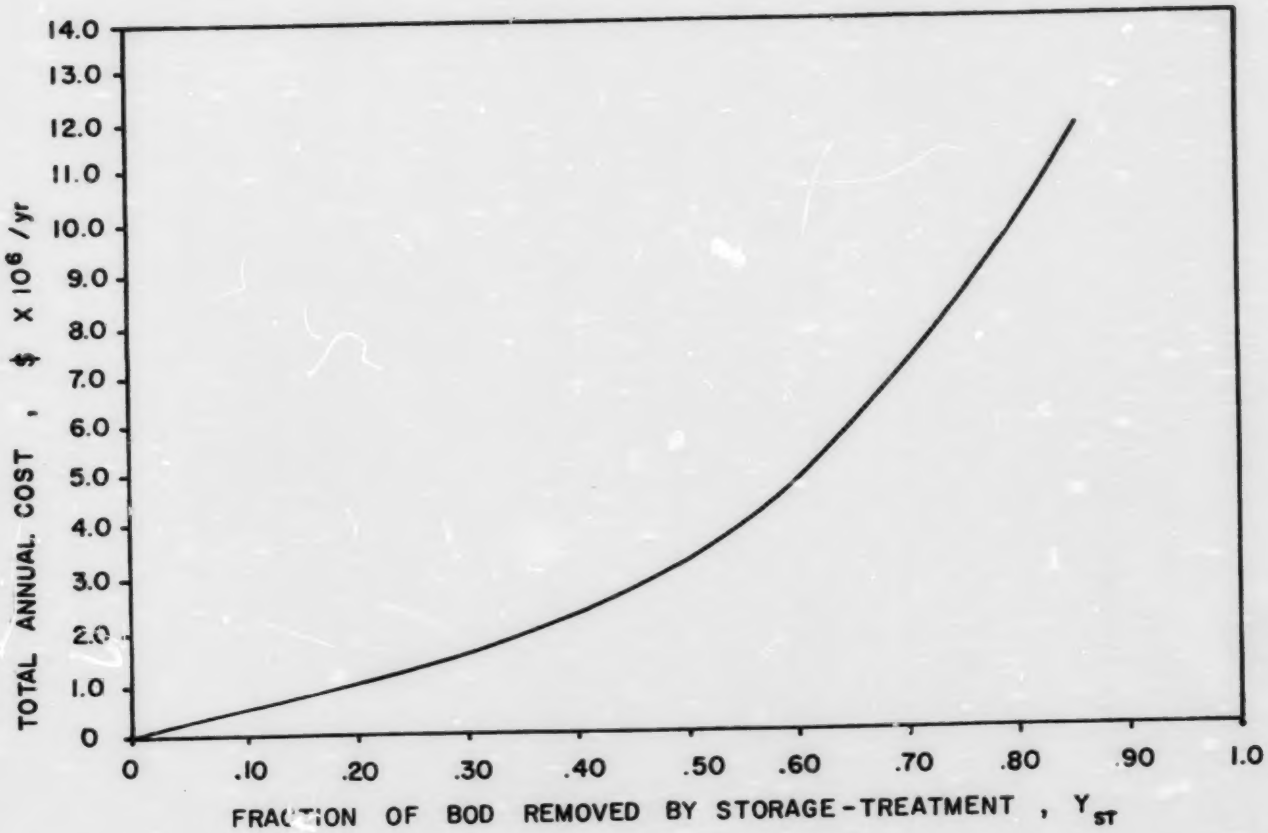


Figure 13. Total Cost Curve for Storage-Treatment, Storm Sewered Areas, Atlanta, Georgia

SECTION VII

APPLICATION TO ANYTOWN, U.S.A.

PROBLEM STATEMENT

In this section, the methodology presented in Section V is applied to a hypothetical urbanized area. The characteristics of this area, called Anytown, necessary to utilize this methodology are derived from average characteristics of the 248 urbanized areas in the U.S. [1]. These averages are:

(1) Population Density (urbanized area): 5.14 persons/ac (12.70 persons/ha).

(2) Mean Annual Precipitation: 33.4 in (84.8 cm).

(3) Land Use Percentage (urbanized area): residential, 31.4%; commercial, 4.6%; industrial, 8.0%; other developed, 9.8%; undeveloped, 46.2%.

(4) Land Use Percentage (developed areas only): residential, 58.4%; commercial, 14.8%; industrial, 8.6%; other developed, 18.2%.

(5) Percent of Developed Area Served by Type of Drainage System: combined sewers, 14.4%; storm sewers, 38.3%; unsewered, 47.3%.

(6) Population Density of the Developed Area by Type of Drainage System--persons/ac (persons/ha): combined, 16.7 (41.3); storm, 13.0 (32.1); unsewered, 4.6 (11.4); all developed areas, 9.6 (23.7).

Assuming a population of 1,000,000 persons and using the above values, the necessary land use, drainage system, and population characteristics for the developed areas in Anytown are derived and shown in Table 9. The land use percentages are assumed to be constant regardless of the drainage system (e.g., combined, storm, and unsewered areas each have 58.4 percent of the service area as residential). Additionally, it is assumed that the population density for each drainage system service area is constant regardless of the land use [e.g., residential, commercial, industrial, and other developed areas in the combined sewered areas all have a population density of 16.7 persons/ac (41.3 persons/ha)].

TABLE 9. LAND USE AND POPULATION CHARACTERISTICS OF ANYTOWN, U.S.A.

Drainage System	Land Use	Area, ac (ha)	Population Density, persons/ac (persons/ha)
Combined	Residential	8800 (3560)	16.7 (41.3)
	Commercial	1300 (530)	16.7 (41.3)
	Industrial	2200 (890)	16.7 (41.3)
	Other	2800 (1130)	16.7 (41.3)
	TOTAL or AVG.	15100 (6110)	16.7 (41.3)
Storm	Residential	23500 (9510)	13.0 (32.1)
	Commercial	3400 (1380)	13.0 (32.1)
	Industrial	5900 (2390)	13.0 (32.1)
	Other	7300 (2950)	13.0 (32.1)
	TOTAL or AVG.	40100 (16230)	13.0 (32.1)
Unsewered	Residential	29000 (11740)	4.6 (11.4)
	Commercial	4200 (1700)	4.6 (11.4)
	Industrial	7300 (2950)	4.6 (11.4)
	Other	9000 (3640)	4.6 (11.4)
	TOTAL or AVG.	49500 (20030)	4.6 (11.4)
TOTAL OR AVG.		104700 (42370)	9.6 (23.7)

The methodology is applied to the control network shown in Figure 14. In effect, the entire procedure is carried out for each drainage system area as though it were a separate entity. Within each system area, a specific control technique applied to one land use is regarded as a separate option. This is primarily due to the fact that the wet-weather BOD load is different for each land use. Therefore, in combined areas, the control network consists of eight options (four for street sweeping and four for sewer flushing) in parallel followed by storage-treatment in series. In the storm sewered areas, the control network consists of the four street sweeping options followed by storage-treatment in series. In the unsewered areas, the only control option is storage-treatment. The notation representing the various land uses and drainage systems found in Figure 14 will be used throughout the remainder of this section.

Before application of the methodology can begin, the wet-weather BOD loads (the pollutant of interest here), for each land use within each drainage system service area, must be estimated. Using the information provided on Table 9 and the relationships found in Appendix A, these values are computed and shown in Table 10. For comparative purposes, the annual wet-weather and dry-weather flows and the dry-weather BOD loads are also shown.

APPLICATION

Following the seven steps discussed and shown in Figures3, 4, 5 and 6 of Section V for each drainage system service area will give an optimal operating strategy applicable to that area. The production functions and total cost curves for the individual parallel options are derived from the information provided in Section VI and Table 9. The gutter length necessary to develop total cost curves for sweeping and flushing was computed from Equation 22 for residential areas and taken from Table 6 for other land uses. The production function and total cost curve for storage-treatment for each drainage system are found by applying the data found in Table 9 and the mean annual precipitation to the simplified assessment procedure discussed by Heaney, Huber, and Nix [7]. Anytown is assumed to be located in Region III [7]. The total cost curves for the fifteen options are presented in Appendix B.

Much uncertainty exists regarding the appropriate values to use for the availability factors for street sweeping (ϕ_{SW}) and sewer flushing (ϕ_{SF}). Thus, three different cases will be analyzed: (1) high availability ($\phi_{SF} = \phi_{SW} = 1.0$), medium availability ($\phi_{SF} = 0.8$, $\phi_{SW} = 0.7$), and low availability ($\phi_{SF} = 0.6$, $\phi_{SW} = 0.4$).

Street sweeping in the storm sewered areas will be used to illustrate how these four options shown in Figure 14 are combined into one equivalent option. The marginal cost curves for these four options and the composite marginal cost curve are shown in Figure 15. Recall that, for a given marginal cost, the pollutant removal by the four options is simply the sum of the individual removals. The removal by option SW4 is insignificant because the pollutant loading per acre is so small. The derived total cost curves for the three cases in the storm sewered area are shown in Figure 16.

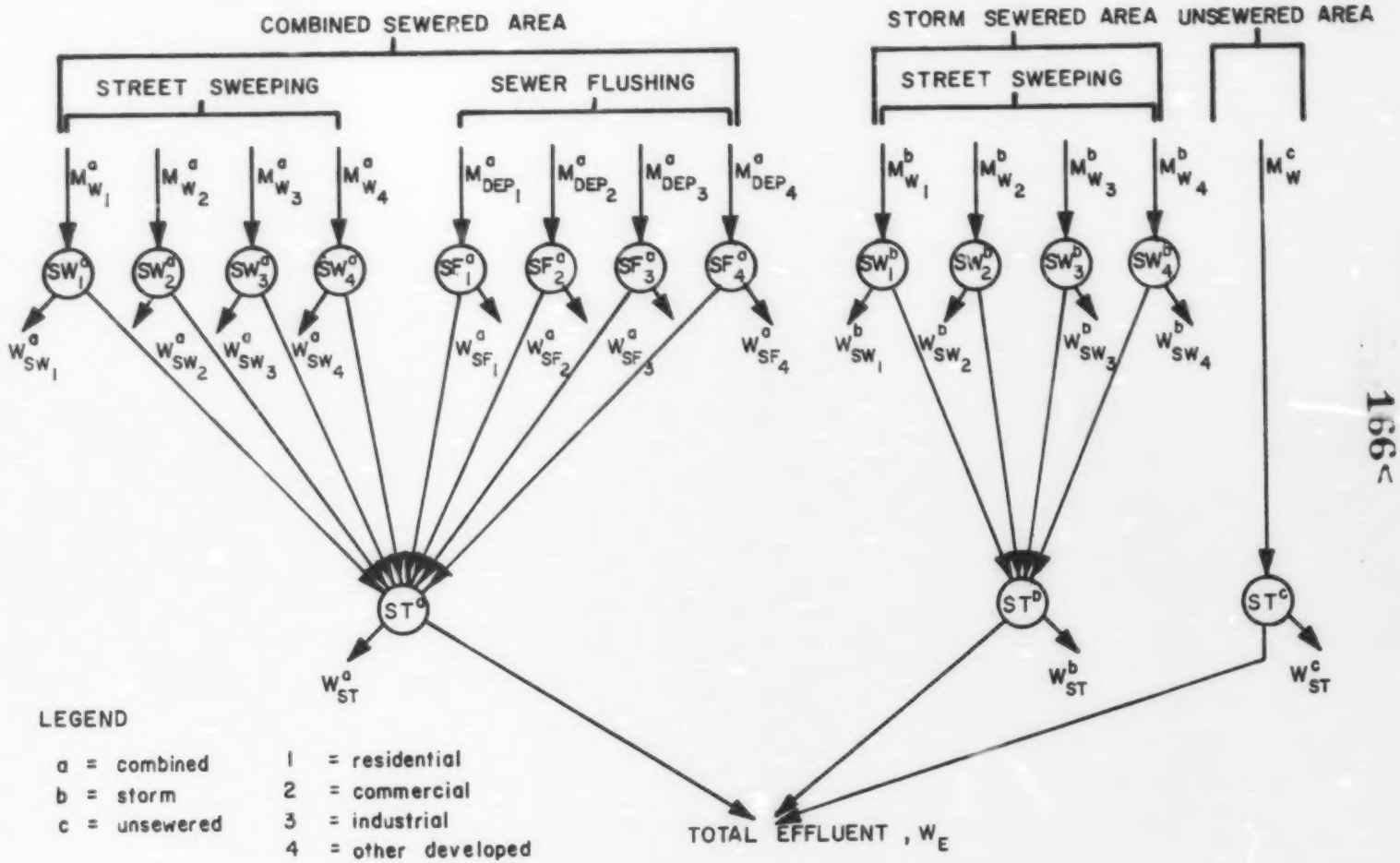


Figure 14. Stormwater Pollution Control Network for Anytown, U.S.A. - Availability Factors Equal 1.0

TABLE 10. ANNUAL WET- AND DRY-WEATHER FLOWS AND BOD LOADS FOR ANYTOWN, U.S.A.

Drainage System	Land Use	Wet-Weather Flow in (cm)	Dry-Weather Flow in (cm)	Dry-Weather BOD Load lb/ac (kg/ha)	Wet-Weather BOD Loads: Street Solids lb/ac (kg/ha)	Sewer Deposition lb/ac (kg/ha)	Street Solids 10^6lb (10^6kg)	Sewer Deposition 10^6lb (10^6kg)
Combined	Residential	13.7 (34.8)	22.4 (56.9)	942 (1057)	30 (34)	95 (107)	0.264 (0.120)	0.836 (0.380)
	Commercial	13.7 (34.8)	22.4 (56.9)	703 (789)	107 (120)	334 (375)	0.139 (0.063)	0.434 (0.197)
	Industrial	13.7 (34.8)	22.4 (56.9)	910 (1021)	40 (45)	127 (142)	0.088 (0.040)	0.279 (0.127)
	Other	13.7 (34.8)	22.4 (56.9)	1035 (1161)	0.5 (0.6)	1.7 (1.9)	0.001 (0.0005)	0.005 (0.002)
	TOTAL	-	-	-	-	-	0.492 (0.223)	1.554 (0.706)
Storm	Residential	12.5 (31.8)	17.4 (44.2)	807 (905)	27 (30)	-	0.634 (0.288)	-
	Commercial	12.5 (31.8)	17.4 (44.2)	807 (905)	107 (120)	-	0.364 (0.165)	-
	Industrial	12.5 (31.8)	17.4 (44.2)	807 (905)	40 (45)	-	0.236 (0.107)	-
	Other	12.5 (31.8)	17.4 (44.2)	807 (905)	0.5 (0.6)	-	0.004 (0.002)	-
	TOTAL	-	-	-	-	-	1.238 (0.562)	-
Unsewered	Residential	8.5 (21.6)	6.2 (15.7)	286 (321)	17 (19)	-	0.493 (0.224)	-
	Commercial	8.5 (21.6)	6.2 (15.7)	286 (321)	107 (120)	-	0.449 (0.204)	-
	Industrial	8.5 (21.6)	6.2 (15.7)	286 (321)	40 (45)	-	0.292 (0.133)	-
	Other	8.5 (21.6)	6.2 (15.7)	286 (321)	0.5 (0.6)	-	0.004 (0.002)	-
	TOTAL	-	-	-	-	-	1.238 (0.563)	
TOTAL							2.968 (1.347)	1.554 (0.706)
					TOTAL (all wet-weather sources)			4.522 (2.053)

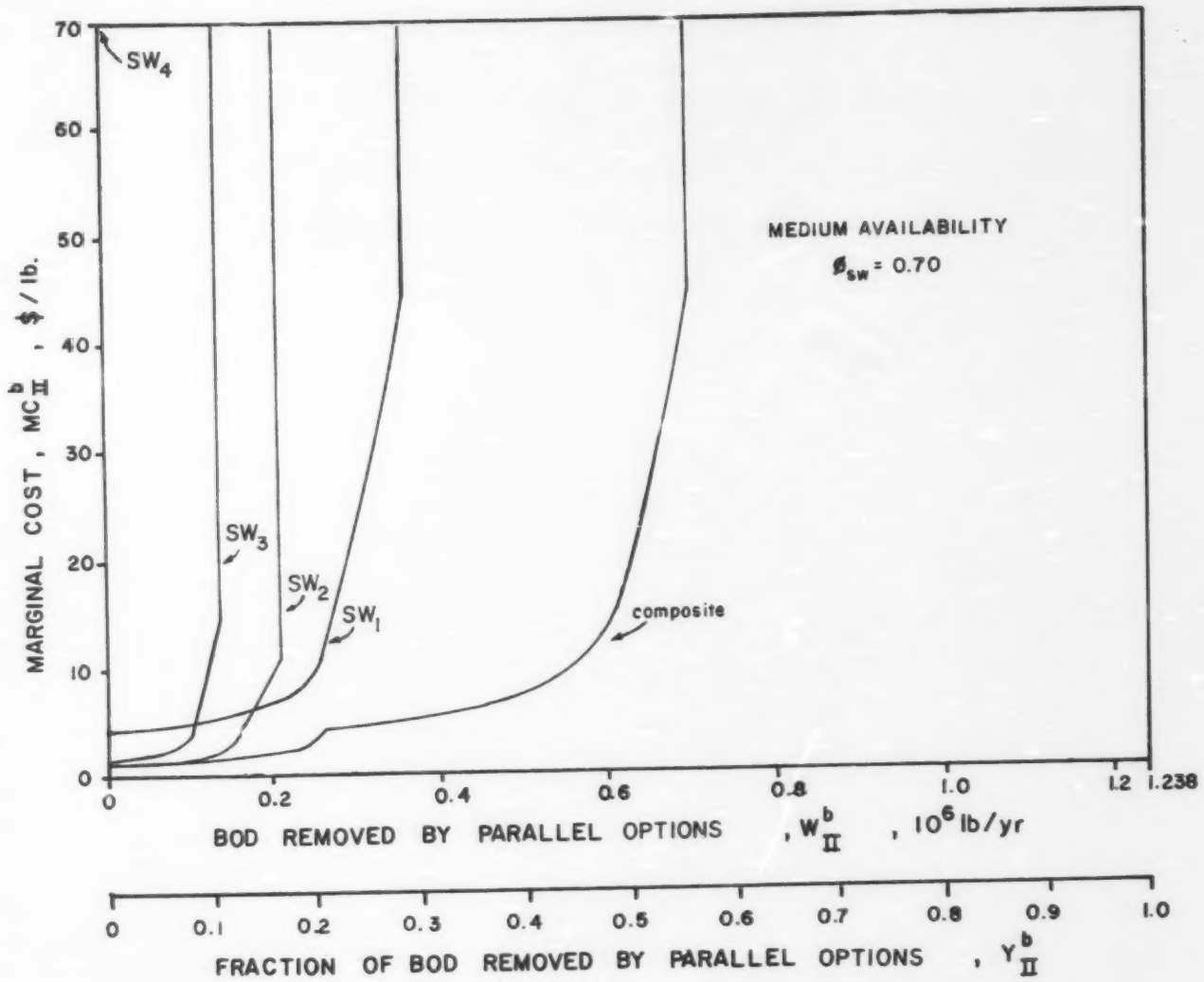


Figure 15. Marginal Cost Curves for the Parallel Options, Storm Areas - Medium Availability Factors

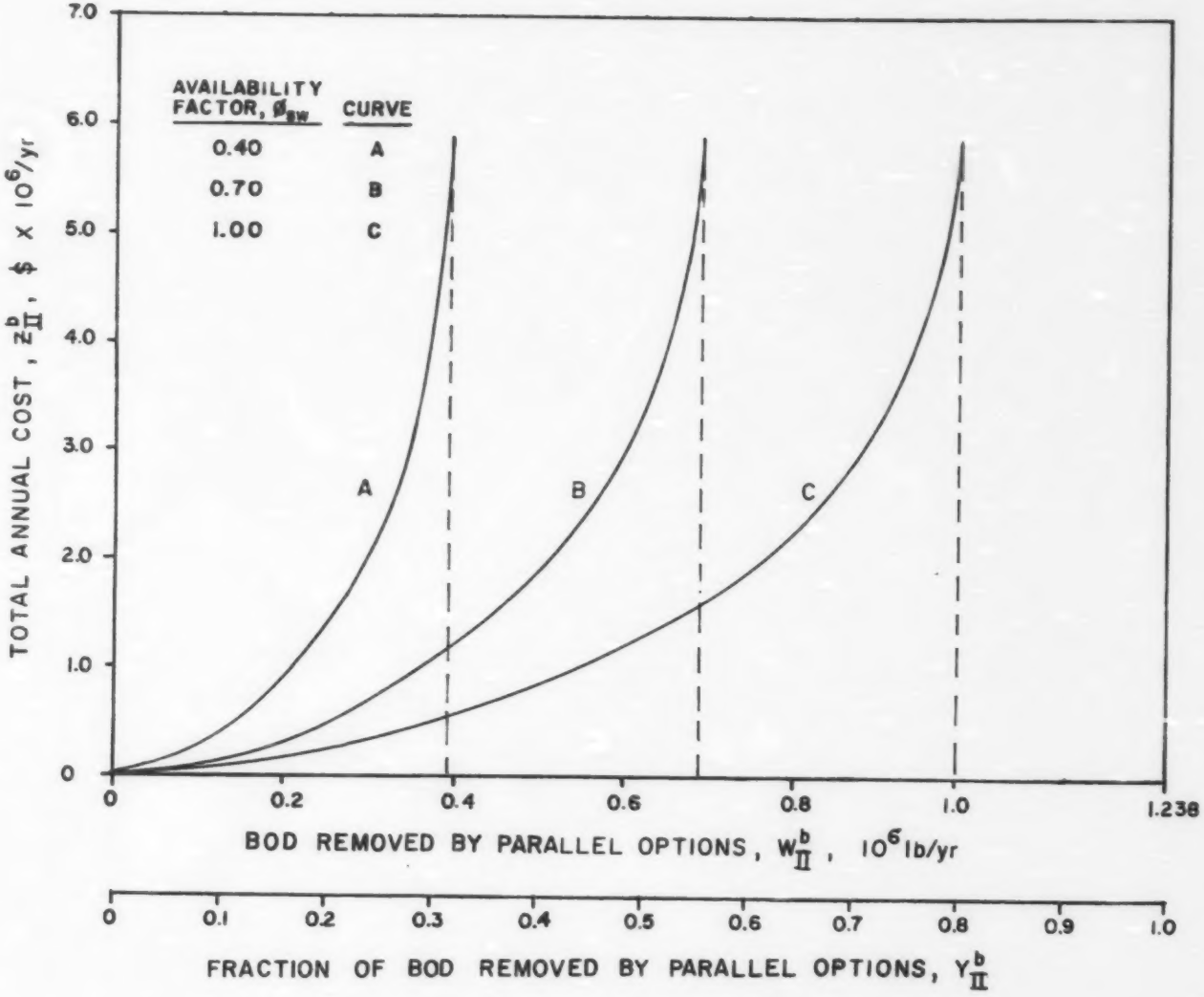


Figure 16. Total Cost Curves for the Parallel Options, Storm Areas

As expected, the total costs increase as the availability factor, ϕ_{SW}, decreases.

For the storm sewer area, the problem is now reduced to evaluating the optimal combination of the composite cost curve for the parallel options and the downstream total cost curve for storage-treatment shown in Figure 17. The resultant optimal solutions for the three assumed availability factors are shown in Figure 18 (ϕ_{SW} = 1.0), Figure 19 (ϕ_{SW} = 0.7), and Figure 20 (ϕ_{SW} = 0.4). In each figure the ordinate and abscissa are scaled so that the maximum cost is used as the upper bound. Thus, the maximum overall pollutant removal is a point in the northwest corner of each figure, e.g., 97 percent in Figure 18. Lastly, the final results for the storm sewered area are shown in Figures 21 (ϕ_{SW} = 1.0), 22 (ϕ_{SW} = 0.7), and 23 (ϕ_{SW} = 0.4).

Identical procedures are used to determine the optimal solutions for the combined sewered area and unsewered area. The result is now simply a case of three options in parallel. These three options are combined to obtain the final results which are presented, by availability factors, in Tables 11 (high), 12 (medium), and 13 (low). Lastly, the final total costs using storage-treatment only, and in conjunction with other management practices, are presented in Figure 24. If the availability factors are high, then the savings from using an integrated program are quite substantial.

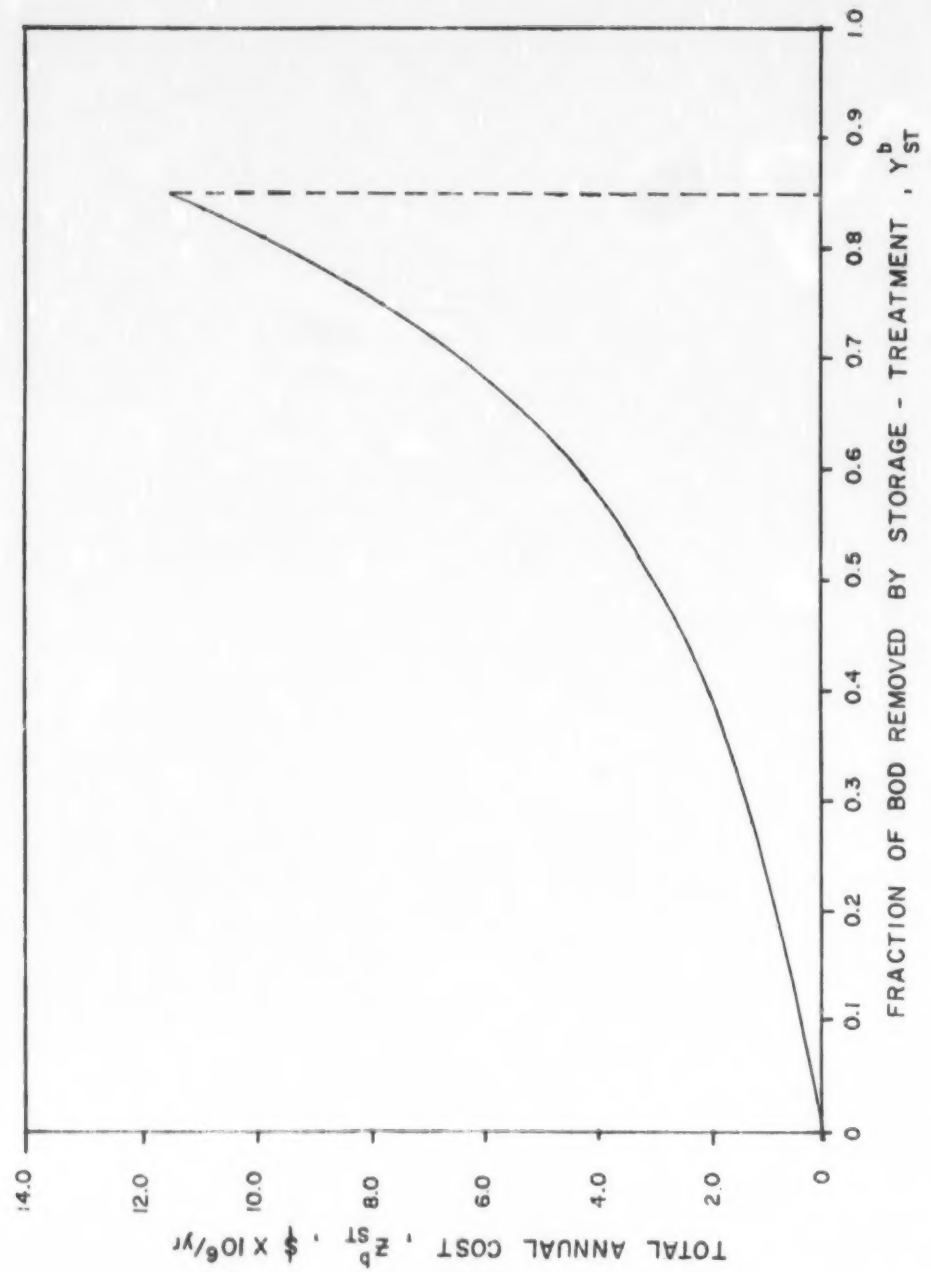


Figure 17. Total Cost Curve for Storage-Treatment, Storm Areas

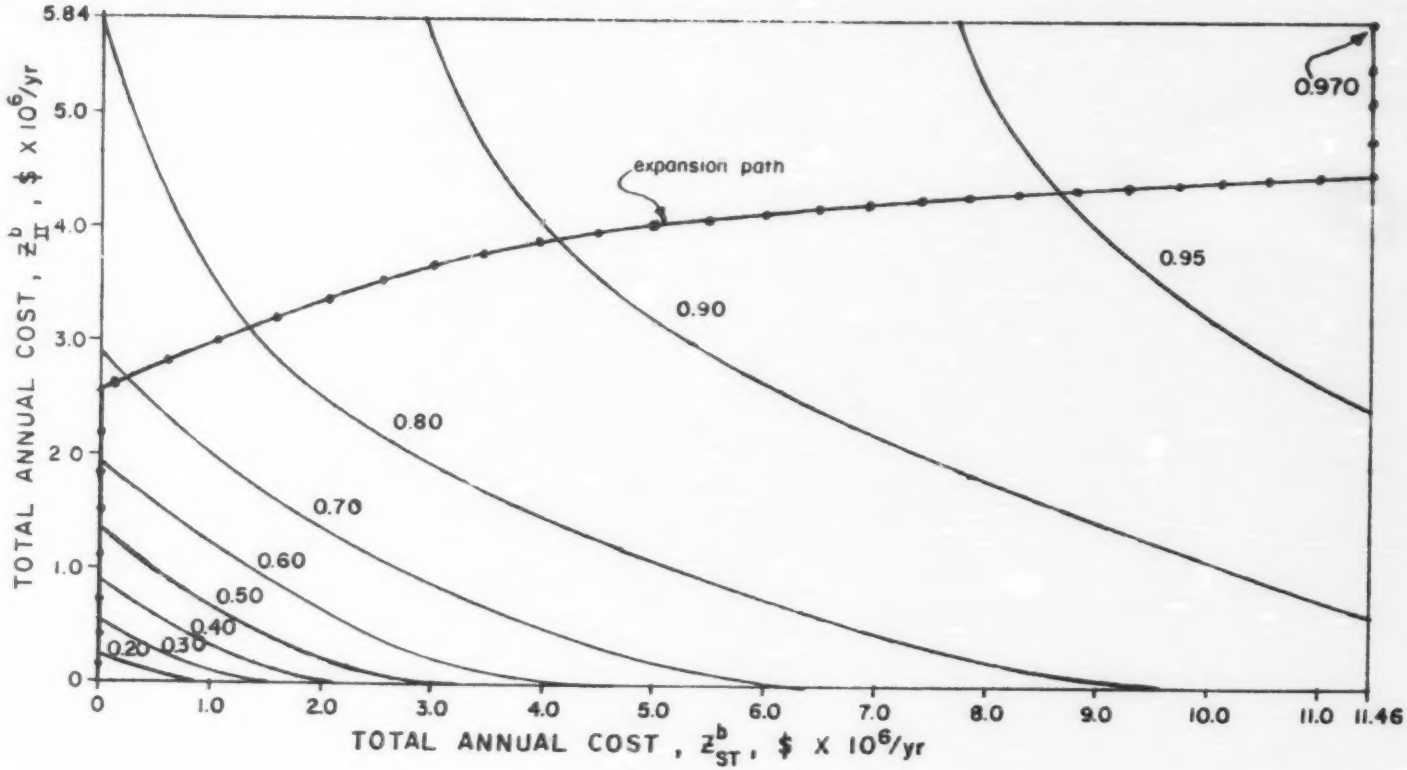


Figure 18. Isoquants of the Overall Fraction of BOD Removed, Storm Areas - High Availability Factors

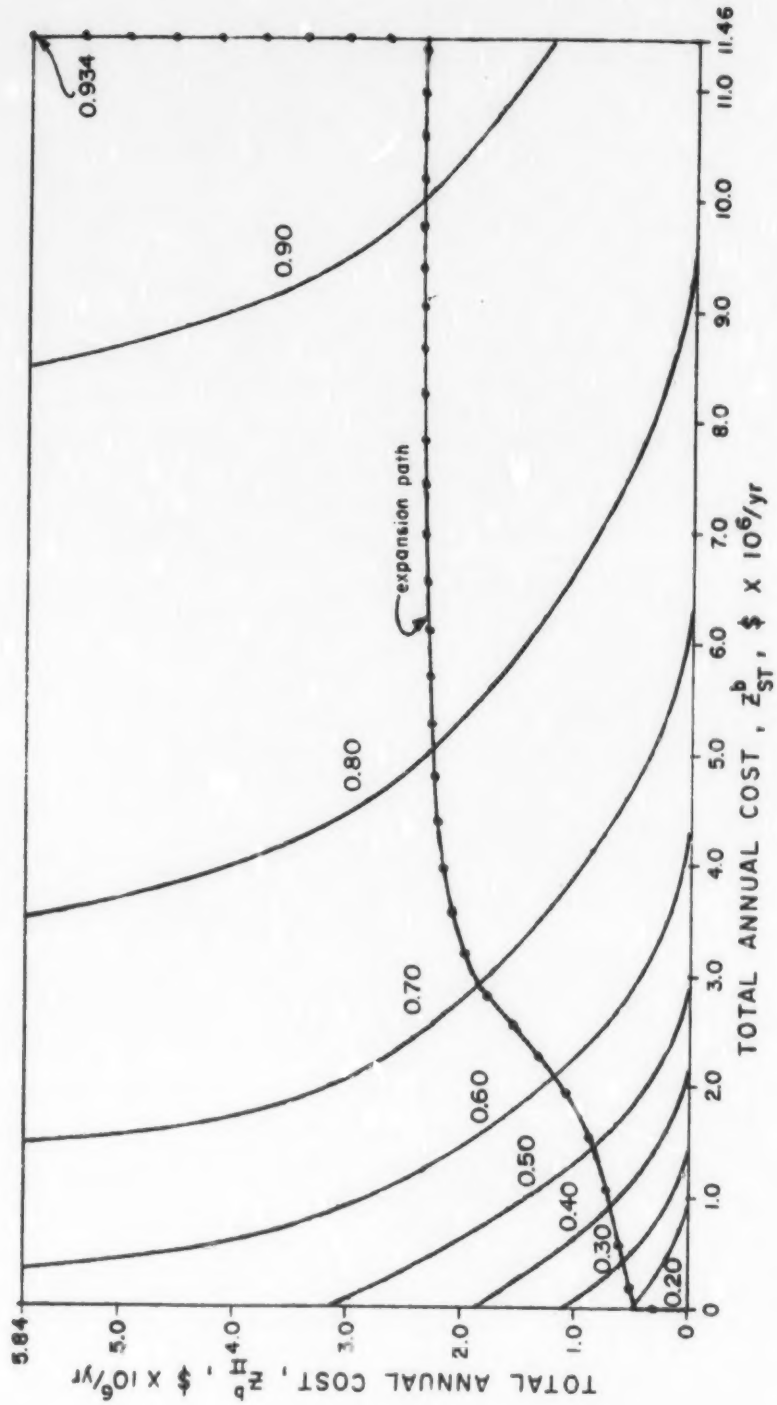


Figure 19. Isoquants of the Overall Fraction of BOD Removed, Storm Areas - Medium Availability Factors

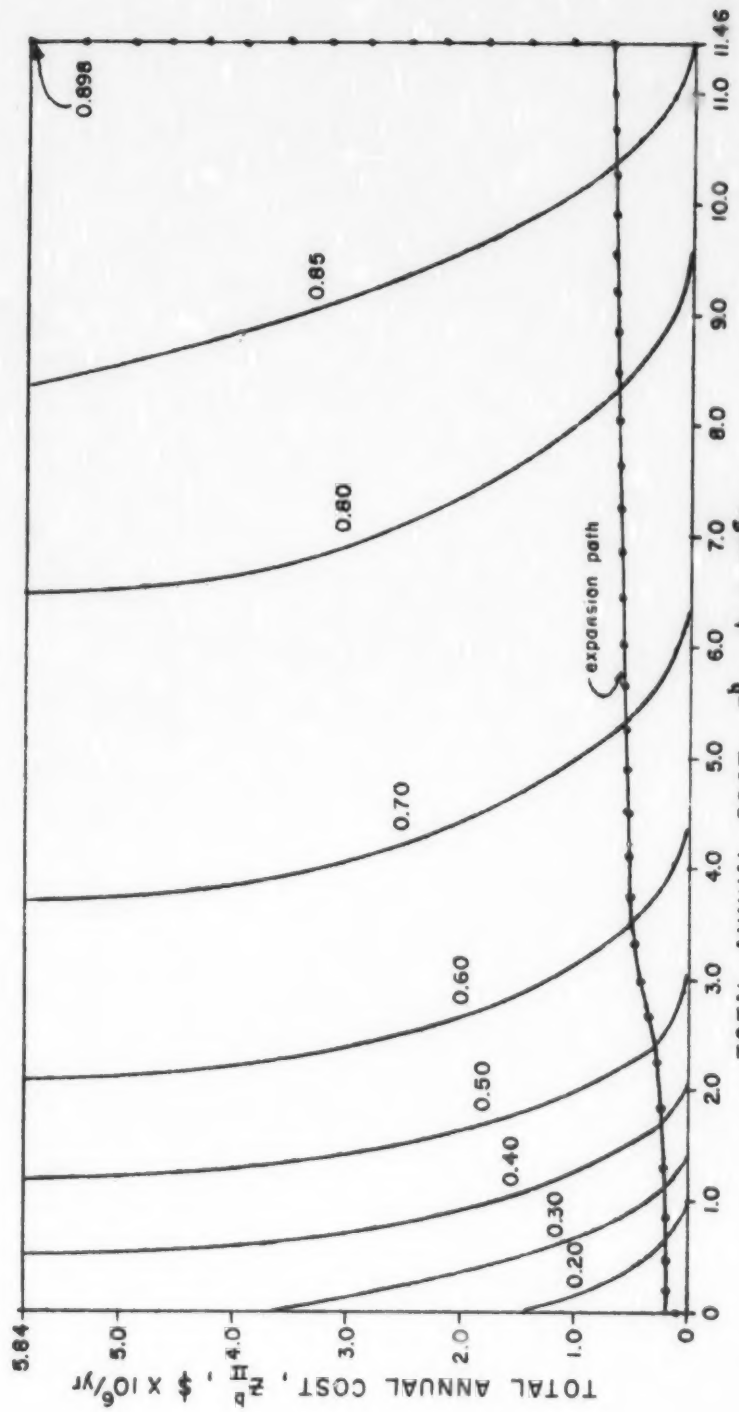


Figure 20. Isoquants of the Overall Fraction of BOD Removed, Storm Areas - Low Availability Factors

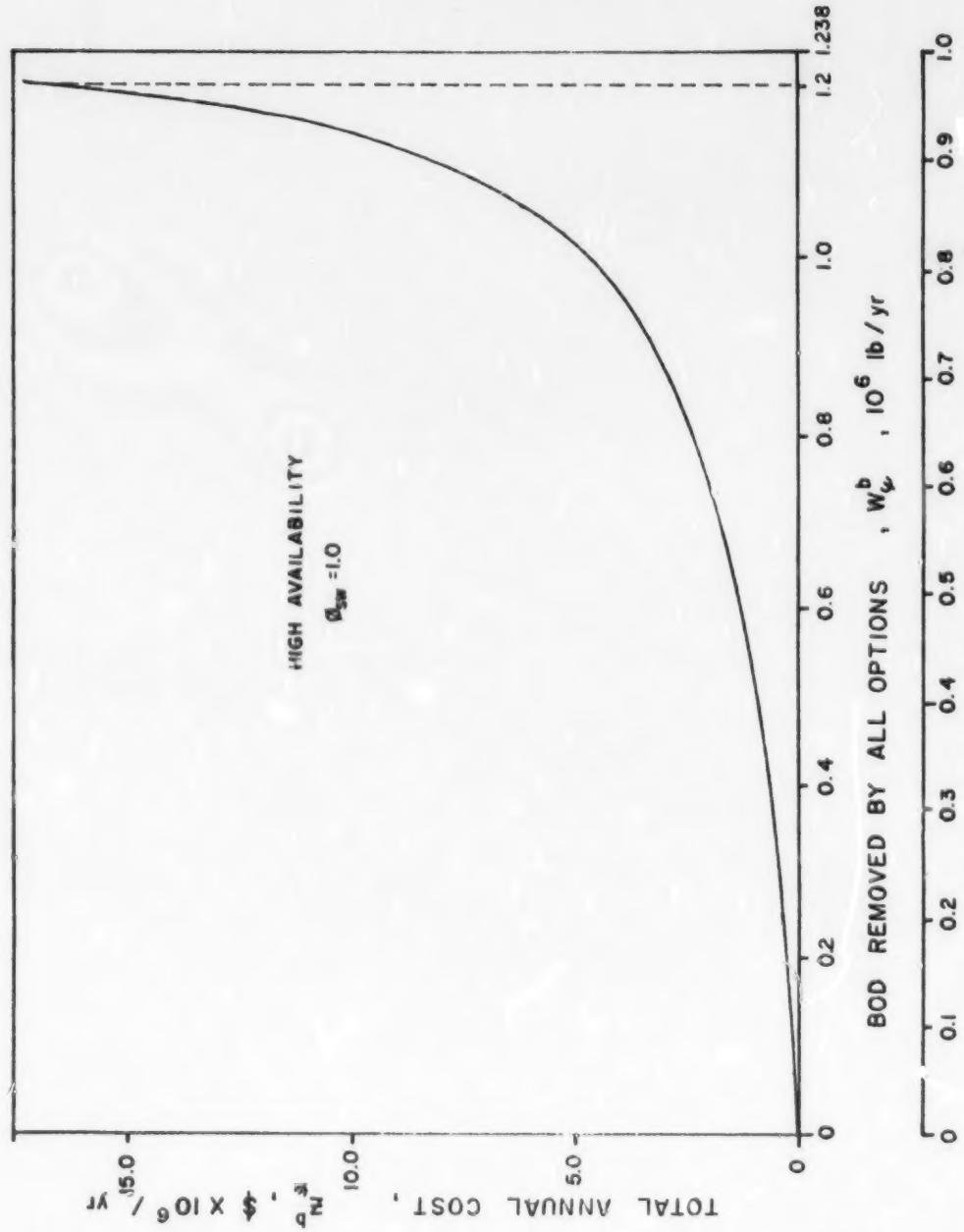


Figure 21. Total Cost Curve for All Options, Storm Areas - High Availability Factors

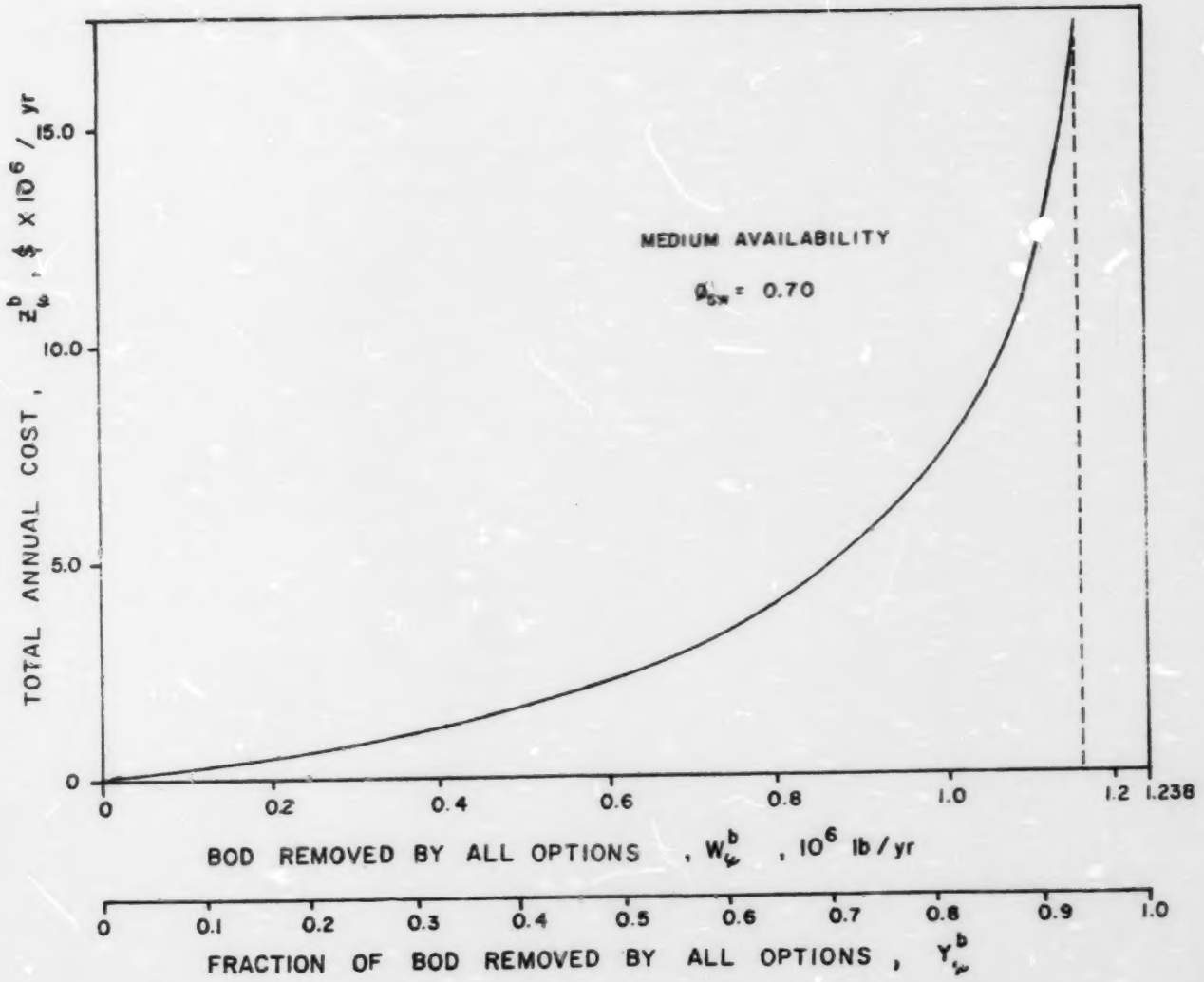


Figure 22. Total Cost Curve for All Options, Storm Areas - Medium Availability Factors

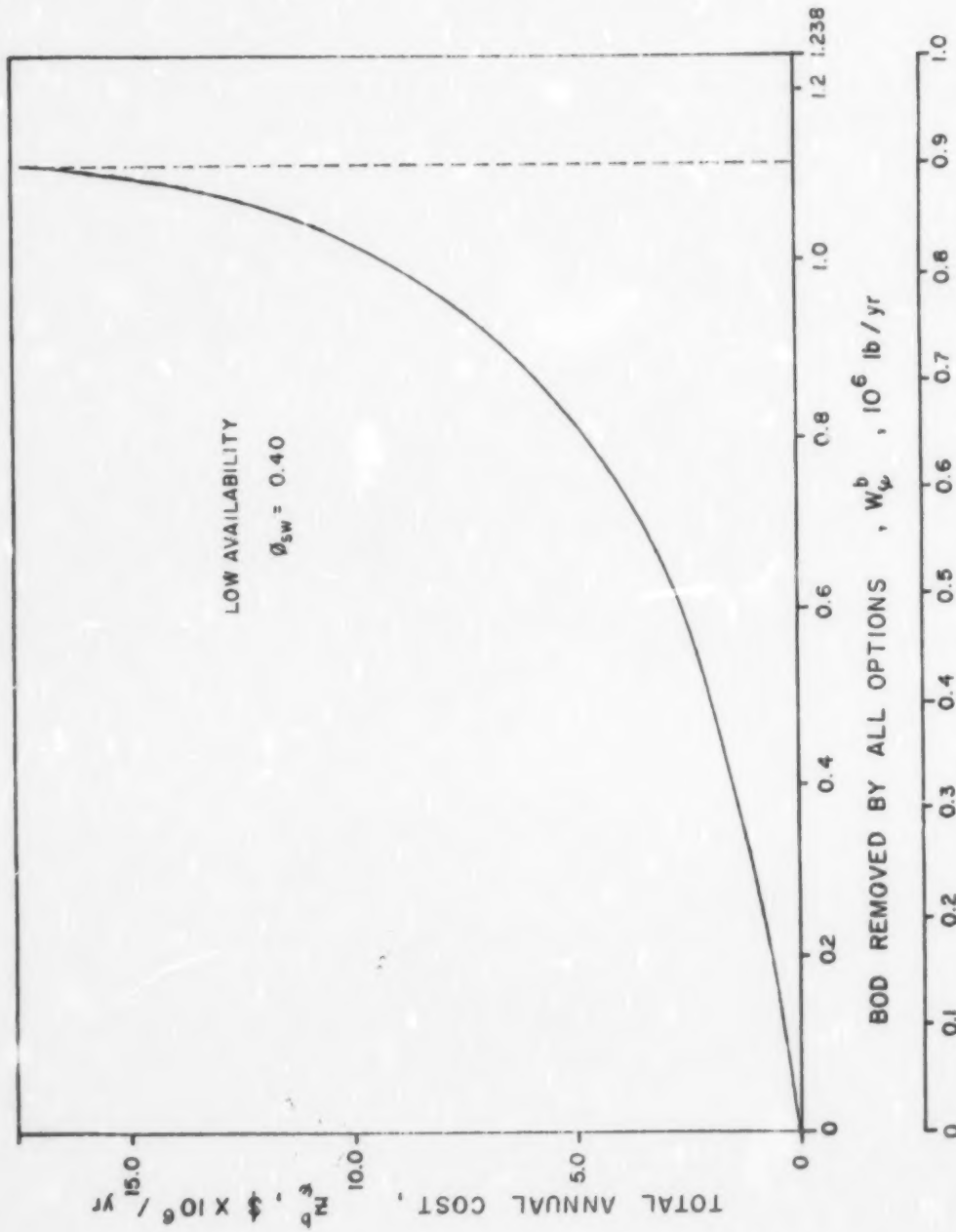


Figure 23. Total Cost Curve for All Options, Storm Areas - Low Availability Factors

TABLE 11. OPTIMAL STRATEGY FOR 25, 50, 75 AND 85 PERCENT OVERALL BOD REMOVAL, ANYTOWN, U.S.A., - HIGH AVAILABILITY FACTORS

Drainage System	Alternatives	Land Use	BOD Removed By Each Process (10^6 lb/yr)				Fraction of Influent BOD Removed By Each Process				Total Cost of Each Process ($ x 10^6/yr)			
			25%	50%	75%	85%	25%	50%	75%	85%	25%	50%	75%	85%
Combined	Street Sweeping	Residential	0	0	0.06	0.11	0	0	0.22	0.43	0	0	0.18	0.39
		Commercial	0.07	0.08	0.09	0.09	0.50	0.56	0.64	0.68	0.07	0.08	0.11	0.13
		Industrial	0.03	0.04	0.05	0.06	0.36	0.49	0.61	0.65	0.04	0.05	0.08	0.09
		Other	0	0	0	0	0	0	0	0	0	0	0	0
	Sewer Flushing	Residential	0.22	0.25	0.30	0.32	0.27	0.29	0.36	0.38	0.08	0.13	0.27	0.35
		Commercial	0.18	0.19	0.24	0.26	0.42	0.45	0.54	0.59	0.06	0.09	0.20	0.29
		Industrial	0.10	0.12	0.14	0.16	0.37	0.42	0.51	0.56	0.04	0.06	0.13	0.18
		Other	0	0	0	0	0	0	0	0	0	0	0	0
	Storage-Treatment		0	0.40	0.65	0.78	0	0.29	0.56	0.75	0	0.85	2.43	5.35
	TOTAL/AVG.		0.60	1.08	1.53	1.78	0.30	0.53	0.75	0.87	0.29	1.26	3.40	6.78
Storm	Street Sweeping	Residential	0	0.09	0.35	0.41	0	0.14	0.56	0.64	0	0.28	1.48	2.07
		Commercial	0.14	0.23	0.29	0.29	0.39	0.63	0.79	0.80	0.12	0.27	0.59	0.61
		Industrial	0.01	0.14	0.18	0.19	0.02	0.59	0.75	0.80	0.01	0.20	0.40	0.51
		Other	0	0	0	0	0	0	0	0	0	0	0	0
	Storage-Treatment		0	0	0	0.12	0	0	0	0.33	0	0	0	1.55
	TOTAL/AVG.		0.15	0.46	0.82	1.01	0.12	0.37	0.66	0.82	0.13	0.75	2.47	4.74
Unsewered TOTAL/AVG.			0.36	0.70	1.05	1.05	0.29	0.57	0.85	0.85	0.43	1.10	2.82	2.82
TOTAL/AVG.			1.11	2.24	3.40	3.84	0.25	0.50	0.75	0.85	0.85	3.11	8.69	14.34

TABLE 12. OPTIMAL STRATEGY FOR 25, 50, 75 AND 85 PERCENT OVERALL BOD REMOVAL, ANYTOWN, U.S.A. - MEDIUM AVAILABILITY FACTORS

Drainage System	Alternatives	Land Use	BOD Removed By Each Process (10^6 lb/yr)				Fraction of Influent BOD Removed By Each Process				Total Cost of Each Process ($ x 10^6/yr)			
			25%	50%	75%	85%	25%	50%	75%	85%	25%	50%	75%	85%
Combined	Street Sweeping	Residential	0	0	0	0.04	0	0	0	0.22	0	0	0	0.18
		Commercial	0.03	0.05	0.06	0.06	0.32	0.48	0.63	0.65	0.04	0.06	0.11	0.11
		Industrial	0	0.02	0.04	0.04	0	0.33	0.58	0.60	0	0.03	0.07	0.08
		Other	0	0	0	0	0	0	0	0	0	0	0	0
	Sewer Flushing	Residential	0.16	0.18	0.24	0.25	0.24	0.27	0.35	0.37	0.06	0.09	0.25	0.30
		Commercial	0.13	0.15	0.19	0.20	0.38	0.42	0.54	0.57	0.05	0.08	0.20	0.25
		Industrial	0.08	0.09	0.11	0.12	0.35	0.38	0.51	0.52	0.03	0.04	0.12	0.14
		Other	0	0	0	0	0	0	0	0	0	0	0	0
	Storage-Treatment		0.18	0.65	0.93	1.08	0.11	0.41	0.66	0.80	0.30	1.35	3.75	6.80
	TOTAL/AVG.		0.58	1.14	1.57	1.79	0.29	0.55	0.77	0.87	0.48	1.65	4.50	7.86
Storm	Street Sweeping	Residential	0	0.01	0.14	0.24	0	0.02	0.33	0.54	0	0.04	0.71	1.39
		Commercial	0.08	0.16	0.17	0.19	0.31	0.62	0.67	0.76	0.10	0.26	0.33	0.49
		Industrial	0.01	0.10	0.10	0.12	0.07	0.59	0.62	0.71	0.02	0.20	0.23	0.33
		Other	0	0	0	0	0	0	0	0	0	0	0	0
	Storage-Treatment		0	0.07	0.36	0.45	0	0.08	0.43	0.65	0	0.32	2.29	5.22
	TOTAL/AVG.		0.09	0.34	0.77	1.00	0.07	0.28	0.63	0.81	0.12	0.82	3.56	7.43
Unsewered TOTAL/AVG.			0.45	0.80	1.05	1.05	0.36	0.65	0.85	0.85	0.56	1.42	2.82	2.82
TOTAL/AVG.			1.12	2.28	3.39	3.84	0.25	0.50	0.75	0.85	1.16	3.89	10.88	18.11

TABLE 13. OPTIMAL STRATEGY FOR 25, 50, 75 AND 85 PERCENT OVERALL BOD REMOVAL, ANYTOWN, U.S.A. - LOW AVAILABILITY FACTORS

Drainage System	Alternatives	Land Use	BOD Removed By Each Process (10^6 lb/yr)				Fraction of Influent BOD Removed By Each Process				Total Cost of Each Process ($ x 10^6/yr)			
			25%	50%	75%	85%	25%	50%	75%	85%	25%	50%	75%	85%
Combined	Street Sweeping	Residential	0	0	0	0.02	0	0	0	0.16	0	0	0	0.14
		Commercial	0	0.01	0.02	0.04	0	0.22	0.43	0.65	0	0.02	0.05	0.11
		Industrial	0	0	0.01	0.02	0	0	0.23	0.57	0	0	0.02	0.07
		Other	0	0	0	0	0	0	0	0	0	0	0	0
	Sewer Flushing	Residential	0.12	0.13	0.14	0.20	0.24	0.26	0.28	0.40	0.06	0.07	0.11	0.47
		Commercial	0.10	0.11	0.12	0.16	0.38	0.40	0.45	0.61	0.05	0.06	0.08	0.34
		Industrial	0.06	0.06	0.07	0.09	0.36	0.39	0.42	0.57	0.03	0.04	0.07	0.20
		Other	0	0	0	0	0	0	0	0	0	0	0	0
	Storage-Treatment		0.37	0.82	1.23	1.29	0.21	0.47	0.73	0.85	0.57	1.80	4.97	8.14
	TOTAL/AVG.		0.65	1.13	1.59	1.82	0.32	0.55	0.78	0.89	0.71	1.99	5.30	9.47
Storm	Street Sweeping	Residential	0	0	0	0.02	0	0	0	0.06	0	0	0	0.12
		Commercial	0	0.06	0.09	0.09	0	0.39	0.64	0.65	0	0.13	0.29	0.29
		Industrial	0	0.02	0.06	0.06	0	0.23	0.59	0.60	0	0.06	0.20	0.21
		Other	0	0	0	0	0	0	0	0	0	0	0	0
	Storage-Treatment		0	0.24	0.61	0.82	0	0.21	0.56	0.77	0	0.89	3.71	8.35
	TOTAL/AVG.		0	0.32	0.76	0.99	0	0.26	0.61	0.80	0	1.08	4.20	8.97
Unsewered TOTAL/AVG.			0.49	0.83	1.05	1.05	0.39	0.67	0.85	0.85	0.61	1.56	2.82	2.82
TOTAL/AVG.			1.14	2.28	3.40	3.86	0.25	0.50	0.75	0.85	1.32	4.63	12.32	21.26

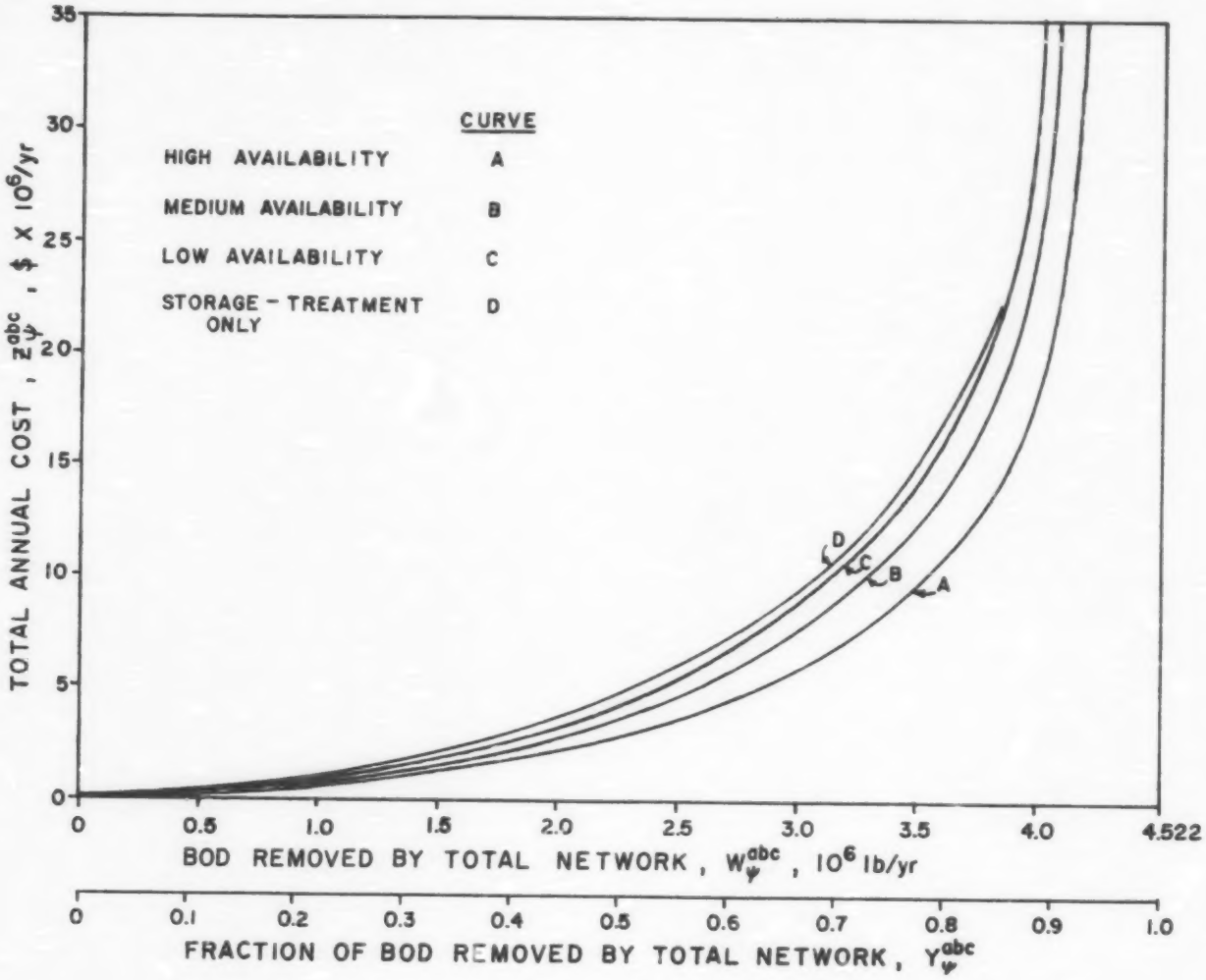


Figure 24. Total Cost Curves for All Drainage System Service Areas

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GLOSSARY

Combined sewage: Sewage containing both domestic sewage and surface water or stormwater, with or without industrial wastes. Includes flow in heavily infiltrated sanitary sewer systems as well as combined sewer systems.

Combined sewer: A sewer receiving both intercepted surface runoff and municipal sewage.

Combined sewer overflow: Flow from a combined sewer in excess of the interceptor capacity that is discharged into a receiving water.

Depression storage: Amount of precipitation which can fall on an area without causing runoff.

Detention: The slowing, dampening, or attenuating of flows either entering the sewer system or within the sewer system by temporarily holding the water on a surface area, in a storage basin, or within the sewer itself.

Domestic sewage: Sewage derived principally from dwellings, business buildings, institutions, and the like. It may or may not contain groundwater.

Isocost lines: Lines of equal cost.

Isoquants: Curves representing combinations of the inputs yielding the same amount of output.

Marginal cost: The rate of change of total cost.

Precipitation event: A precipitation event terminates if zero rainfall has been recorded for the previous specified time interval.

Production function: Locus of technologically efficient combinations of inputs and outputs.

Runoff coefficient: Fraction of rainfall that appears as runoff after subtracting depression storage and interception. Typically accounts for infiltration into ground and evaporation.

Storm flow: Overland flow, sewer flow, or receiving stream flow caused totally or partially by surface runoff or snowmelt.

Storm sewer: A sewer that carries intercepted surface runoff, street wash and other wash waters, or drainage, but excludes domestic sewage and industrial wastes.

Storm sewer discharge: Flow from a storm sewer that is discharged into a receiving water.

Stormwater: Water resulting from precipitation which either percolates into the soil, runs off freely from the surface, or is captured by storm sewer, combined sewer, and to a limited degree sanitary sewer facilities.

Surface runoff: Precipitation that falls onto the surfaces of roofs, streets, ground, etc., and is not absorbed or retained by that surface, thereby collecting and running off.

APPENDIX A

QUANTITY AND QUALITY ANALYSIS

In order to develop an optimal stormwater pollution control strategy, the magnitude of the problem must be estimated. Several methods are available to estimate the quantity and quality of urban runoff. A simplied method to assess stormwater pollution loads and control costs by Heaney, Huber, and Nix can be used to compute these parameters for any urbanized area [A1]. In addition to the runoff estimations, equations are presented to determine the corresponding dry-weather (sanitary sewage) flows and quality. This methodology is briefly described below. The following equations may be applied to any land use or sewerage system service area.

Annual runoff may be estimated by the following equation:

$$AR = (0.15 + 0.75\ (I/100))\ P - 5.234\ DS^{0.5957} \qquad (A1)$$

where AR = annual runoff, in;

I = total imperviousness, percent;

P = annual precipitation, in; and

DS = annual depression storage, in.

The annual depression storage is an index of the available areas capable of retaining precipitation. This parameter is determined by the following relationship,

$$DS = 0.25 - 0.1875\ (I/100). \qquad (A2)$$

The equation used to estimate imperviousness is

$$I = 9.6\ PD_d^{(0.573-0.0391\ \log_{10}PD_d)} \qquad (A3)$$

where PD_d = population density in the developed area, persons/ac.

Knowing the population density of the area allows the annual runoff to be quickly determined.

The dry-weather flow may be estimated by the following equation,

$$DWF = 1.34\ PD_d \qquad (A4)$$

where DWF = dry weather flow, in/hr.

This relationship is based on an assumed dry-weather flow of 100 gallons/capita-day (378ℓ/capita-day).

Estimating the quality of urban runoff presents a more difficult task. Available data indicate wide variation in estimated pollutant loads. If annual pollutant loads are assumed to vary as a function of population density, precipitation, land use and type of sewerage system, the following relationships may be used:

$$m_W = \beta(i,j) \cdot P \cdot f_i(PD_d) \quad \text{for combined sewered areas,} \qquad (A5)$$

and

$$m_W = \alpha(i,j) \cdot P \cdot f_i(PD_d) \quad \text{for storm and unsewered areas,} \qquad (A6)$$

where m_W = annual wet weather pollutant load, lb/ac-yr;

P = annual precipitation, in/yr;

$f_i(PD_d)$ = population density function for land use i;

$\alpha(i,j)$ = coefficient for storm and unsewered areas for pollutant j on land use i, lb/ac-yr-in; and

$\beta(i,j)$ = coefficient for combined sewered areas for pollutant j on land use i, lb/ac-yr-in.

Values of $\alpha(i,j)$, $\beta(i,j)$ and $f_i(PD)$ are shown in Table AI.

The equation used to estimate dry-weather quality, in terms of BOD, is

$$m_{Dw} = 62.1\ PD_d - m_{DEP} \qquad (A7)$$

where m_{Dw} = annual dry-weather BOD load, lb/ac-yr; and

m_{DEP} = annual BOD load of combined sewer deposition, lb/ac-yr.

This estimate assumes a per capita BOD discharge of 0.17 lbs (77 gm)/day.

Combined sewer deposition is defined as that portion of the dry-weather pollutant load that is deposited in the combined sewers, usually due to inadequate carrying velocities. Often, this load is flushed from the sewers during runoff periods and becomes part of the stormwater discharge. The deposition may be estimated by computing the difference between combined and storm sewered area BOD loadings derived for the combined area of concern.

TABLE A1. POLLUTANT LOADING FACTORS

Land Uses: i = 1 Residential
i = 2 Commercial
i = 3 Industrial
i = 4 Other (assume $PD_d = 0$)

Pollutants: j = 1 BOD_5, Total
j = 2 Suspended Solids (SS)
j = 3 Volatile Solids, Total (VS)
j = 4 Total PO_4 (as PO_4)
j = 5 Total N

Population Function: $i = 1 \quad f_i(PD_d) = 0.142 + 0.218 \cdot PD_d^{0.54}$
$i = 2,3 \quad f_i(PD_d) = 1.0$
$i = 4 \quad f_i(PD_d) = 0.142$

α and β Factors for Equations: Storm factors, α, and combined factors, β, have units lb/ac-yr-in.

		Pollutant, j				
		1. BOD_5	2. SS	3. VS	4. PO_4	5. N
Storm Areas, α	1. Residential	0.799	16.3	9.45	0.0336	0.131
	2. Commercial	3.20	22.2	14.0	0.0757	0.296
	3. Industrial	1.21	29.1	14.3	0.0705	0.277
	4. Other	0.113	2.70	2.6	0.00994	0.0605
Combined Areas, β	1. Residential	3.29	67.2	38.9	0.139	0.540
	2. Commercial	13.2	91.8	57.9	0.312	1.22
	3. Industrial	5.00	120.0	59.2	0.291	1.14
	4. Other	0.467	11.1	10.8	0.0411	0.250

Source: Heaney, J.P., Huber, W.C., and Nix, S.J., "Storm Water Management Model: Level I--Preliminary Screening Procedures," USEPA Report EPA-600/2-76-275, October 1976, p. 17.

This assumes that the greater loads experienced by combined areas are due to the deposition of dry-weather solids. Thus, combined sewer deposition is estimated by the following equation:

$$m_{DEP} = (\beta(i,j)-\alpha(i,j)) \cdot P \cdot f_1(PD_d). \qquad (A8)$$

Of course, for storm sewered and unsewered areas, deposition from dry-weather sources is not computed unless there are illicit connections of sewage to the storm sewers.

REFERENCE

A1. Heaney, J. P., Huber, W. C., and S. J. Nix, "Storm-Water Management Model: Level I--Preliminary Screening Procedures," EPA-600/2-76-275, Cincinnati, Ohio, Oct. 1976.

APPENDIX B

WORKING CURVES FOR GRAPHICAL SOLUTION

The basic curves for the analysis consist of one curve for each option showing total cost as a function of pounds of pollutant removed, and level of pollutant control. The scaling of each curve is set by the total cost as a a function of the level of pollution control which ranges from 0 to 1. The actual pounds removed differ as a function of the availability factor, ϕ, and the total load, M. Thus, the scaling on this abscissa is set up as a function of ϕ. The curves are arranged as follows:

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B5-B8	Total Cost Curves for Combined Sewered Areas, by Land Use, Sewer Flushing	78-81
B9-B12	Total Cost Curves for Storm Sewered Areas, by Land Use, Street Sweeping	82-85
B13-B15	Total Cost Curves for Storage-Treatment, by Type of Sewerage System	86-88

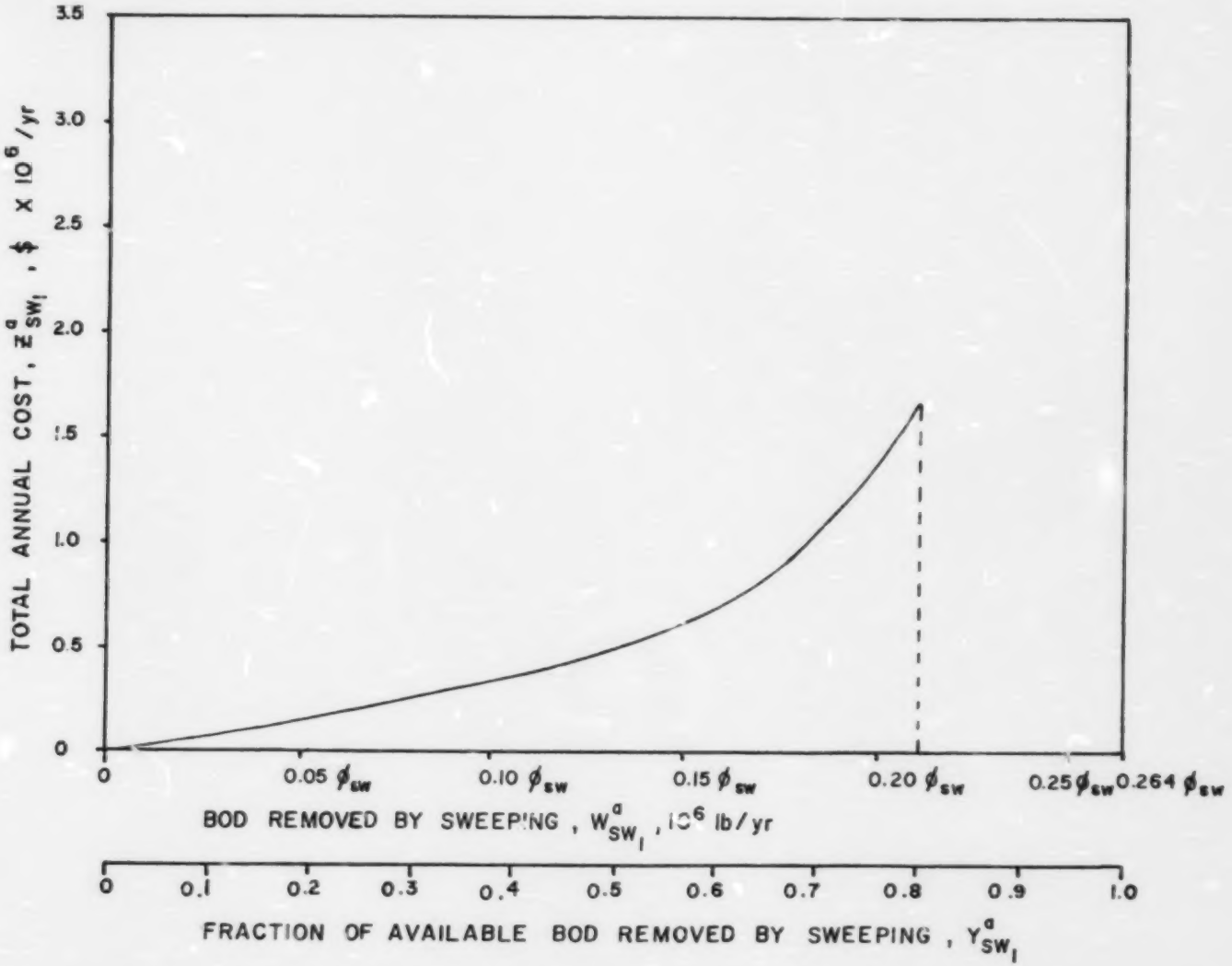

Figure B1. Total Cost Curve for Residential Portion of Combined Sewered Areas, Street Sweeping

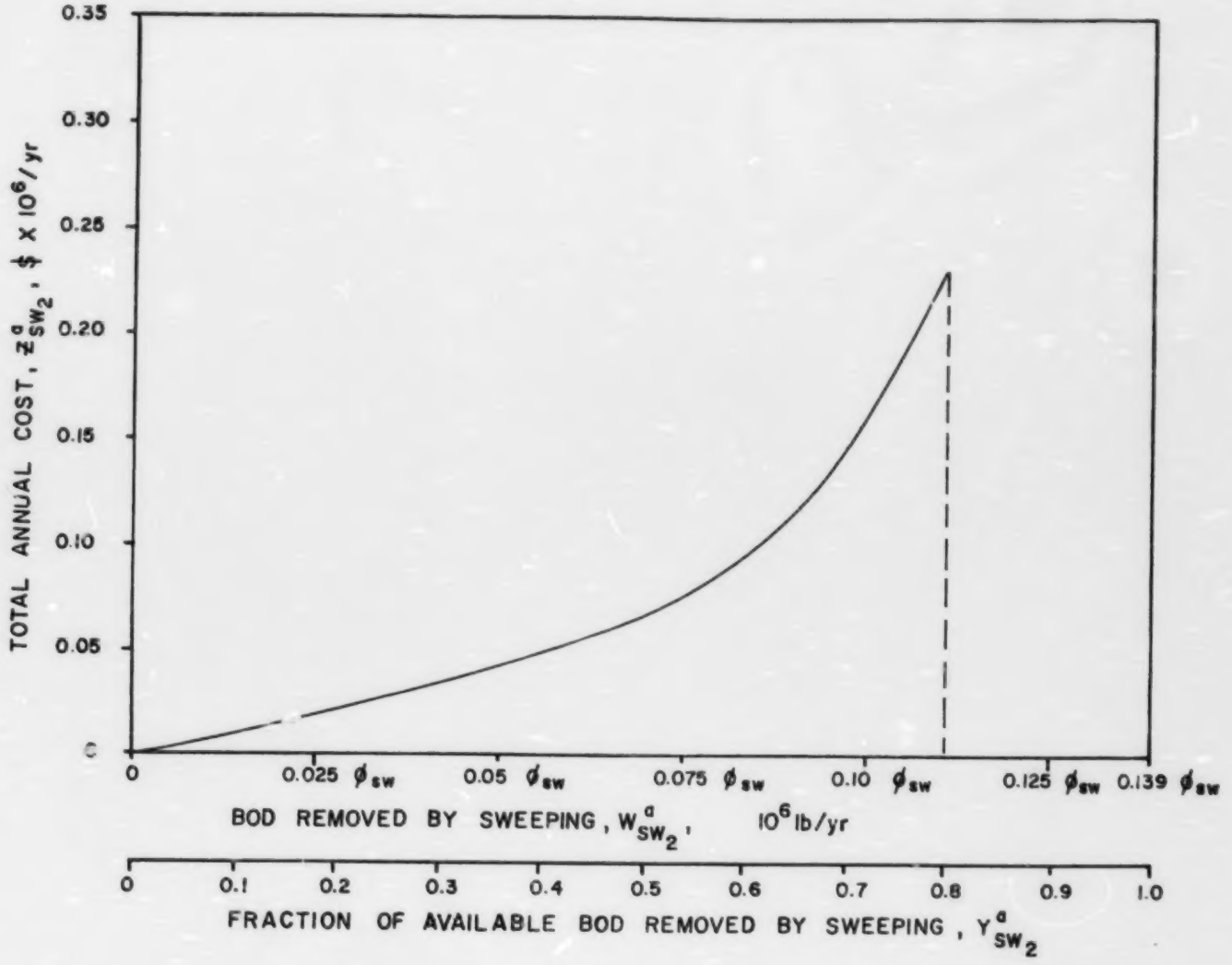

Figure B2. Total Cost Curve for Commercial Portion of Combined Sewered Areas, Street Sweeping

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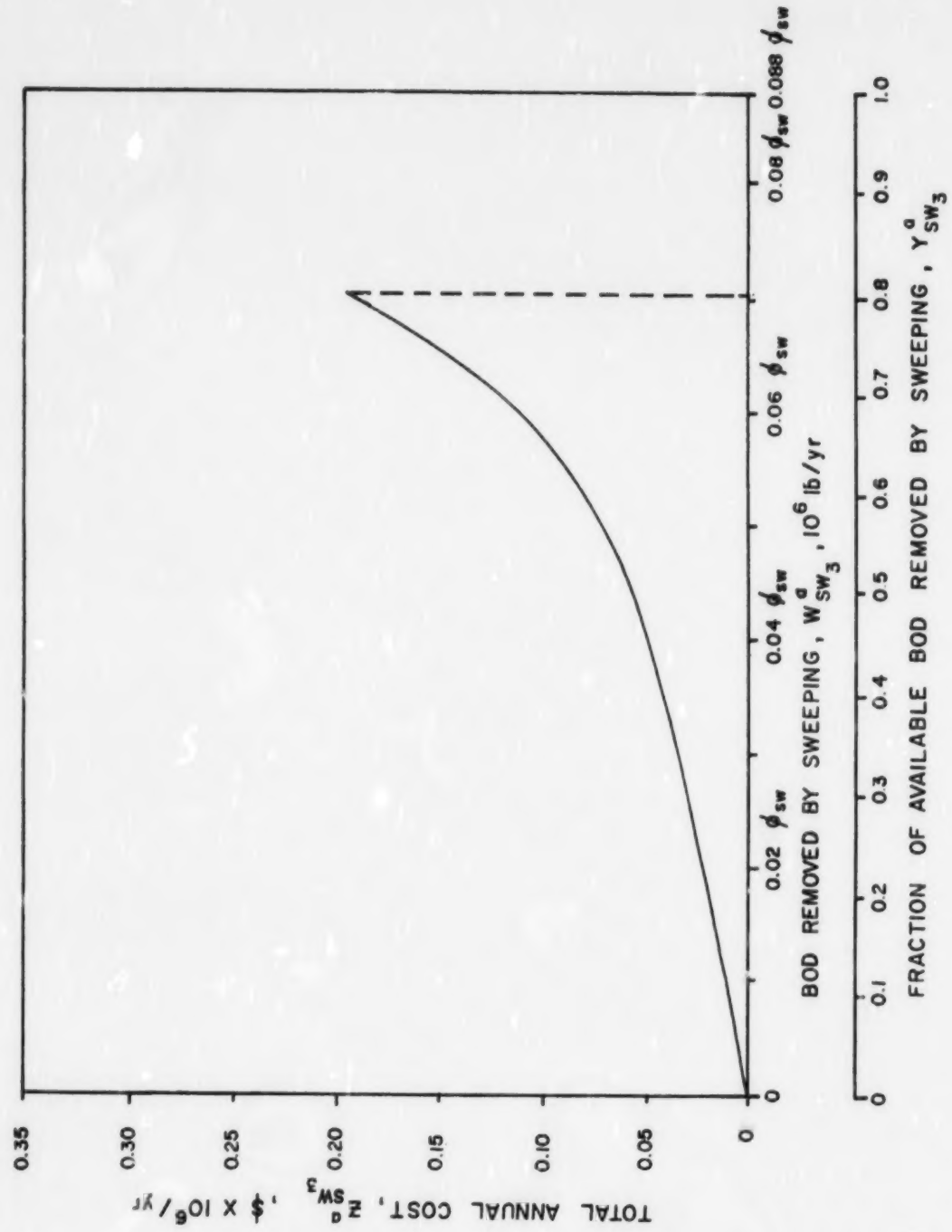

Figure B3. Total Cost Curve for Industrial Portion of Combined Sewered Areas, Street Sweeping

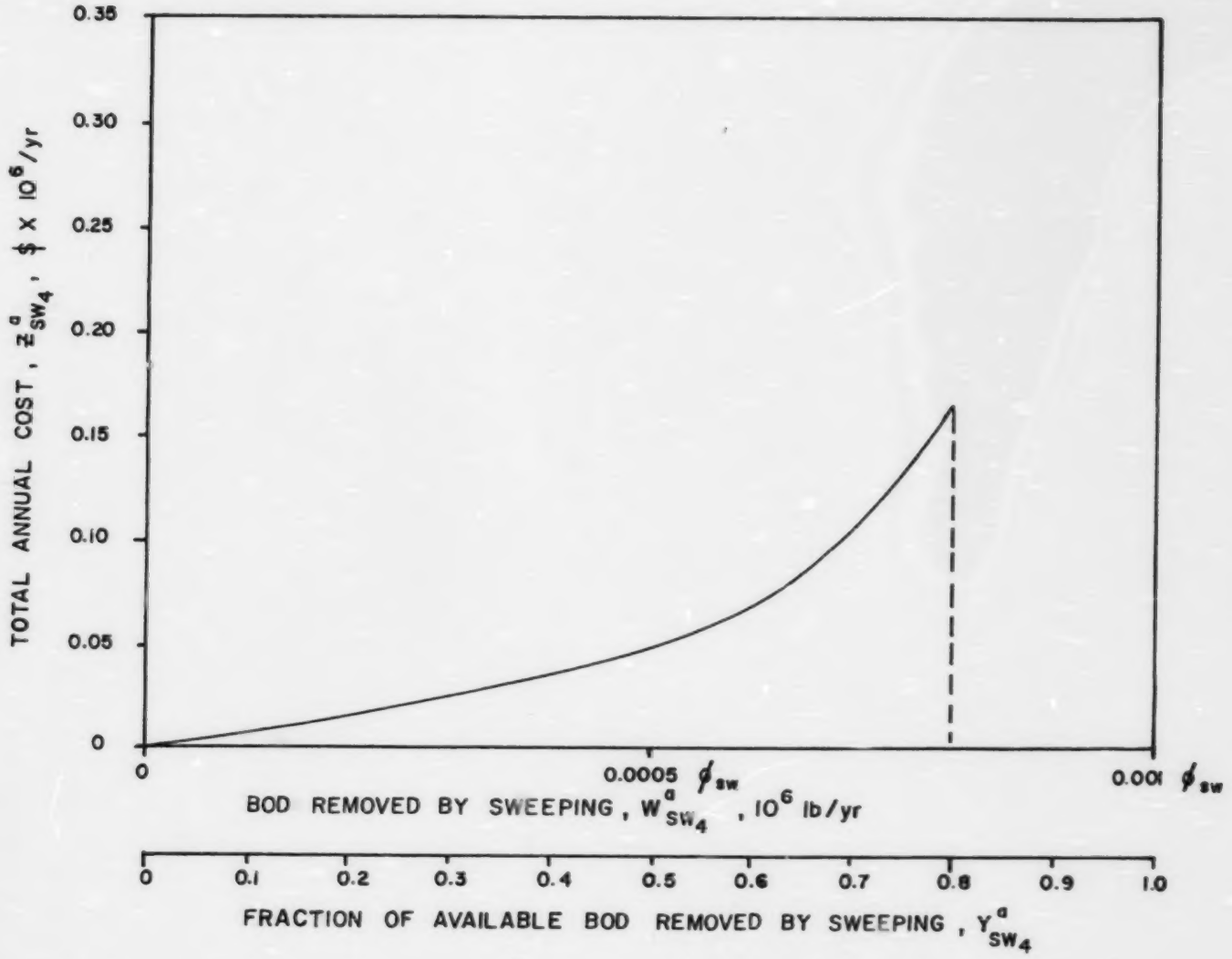

Figure B4. Total Cost Curve for Other Portion of Combined Sewered Areas, Street Sweeping

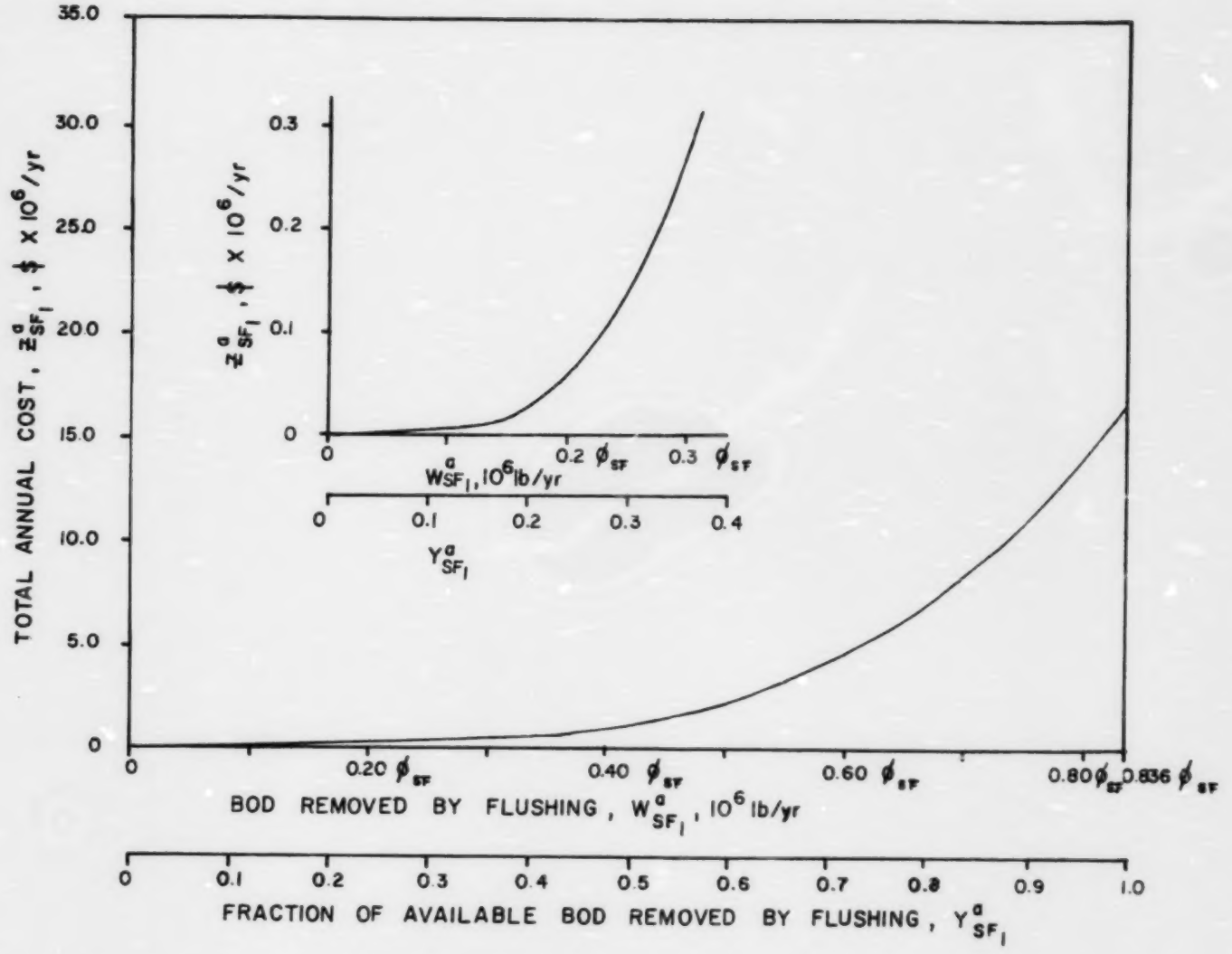

Figure B5. Total Cost Curve for Residential Portion of Combined Sewered Areas, Sewer Flushing

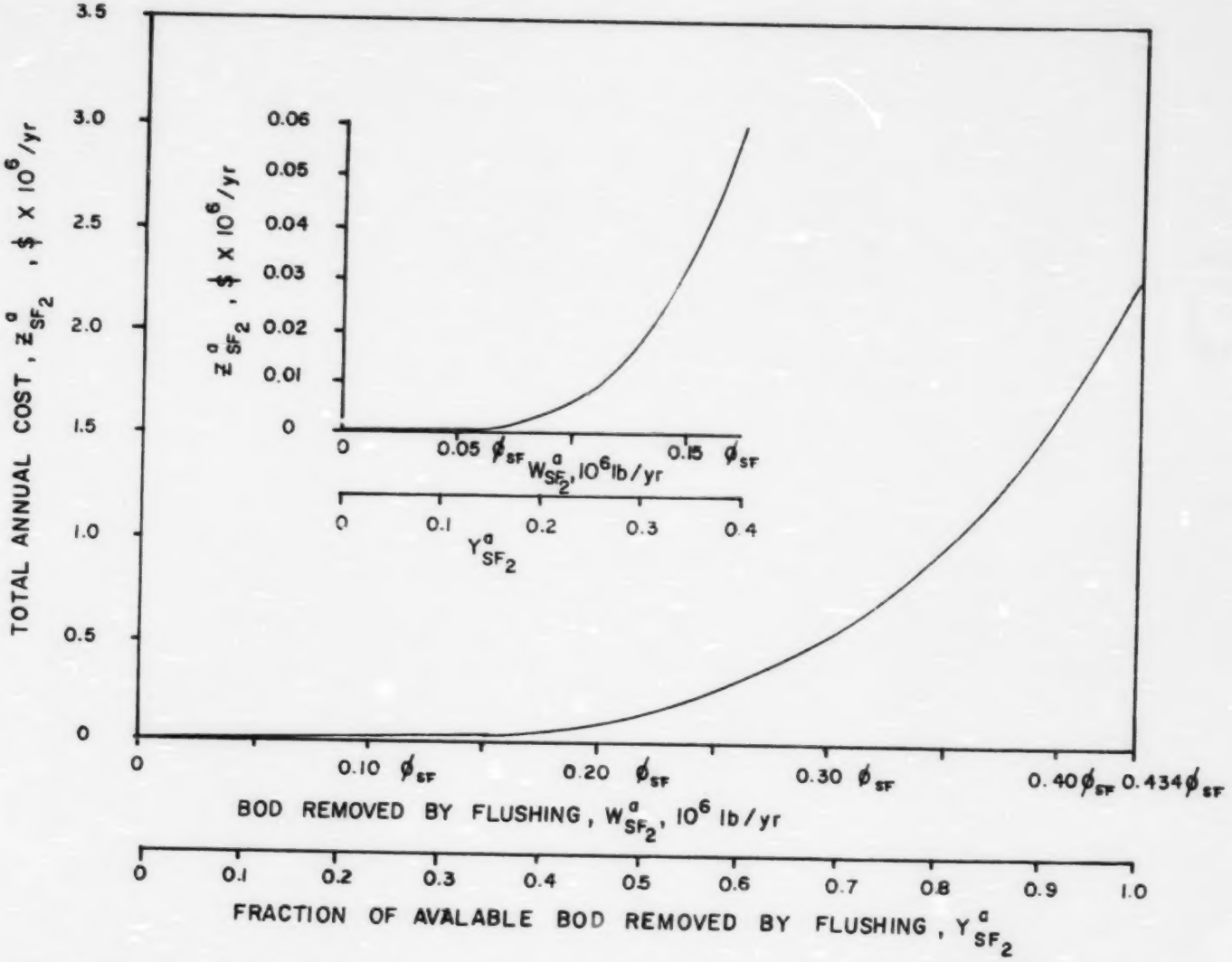

Figure B6. Total Cost Curve for Commercial Portion of Combined Sewered Areas, Sewer Flushing

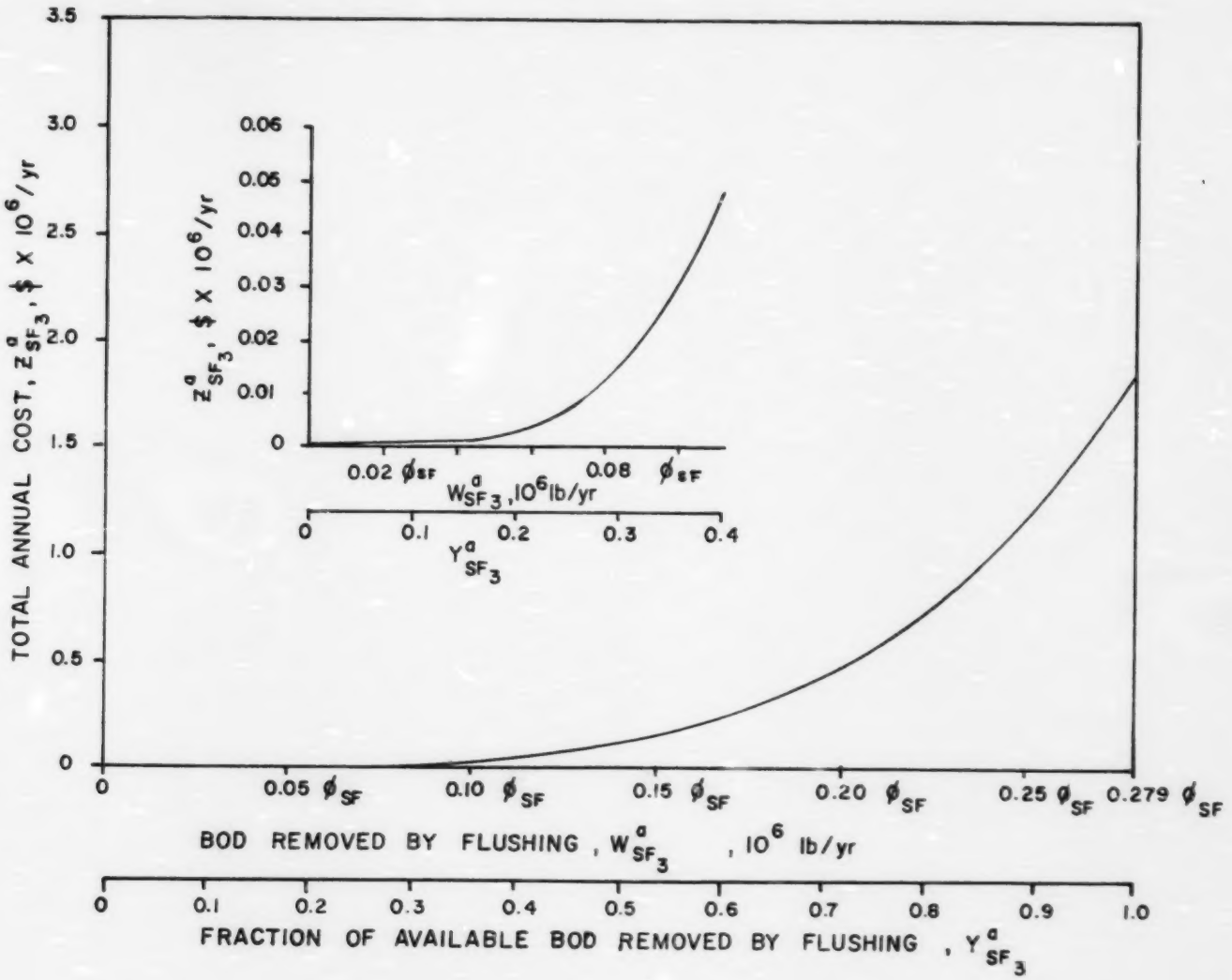

Figure B7. Total Cost Curve for Industrial Portion of Combined Sewered Areas, Sewer Flushing

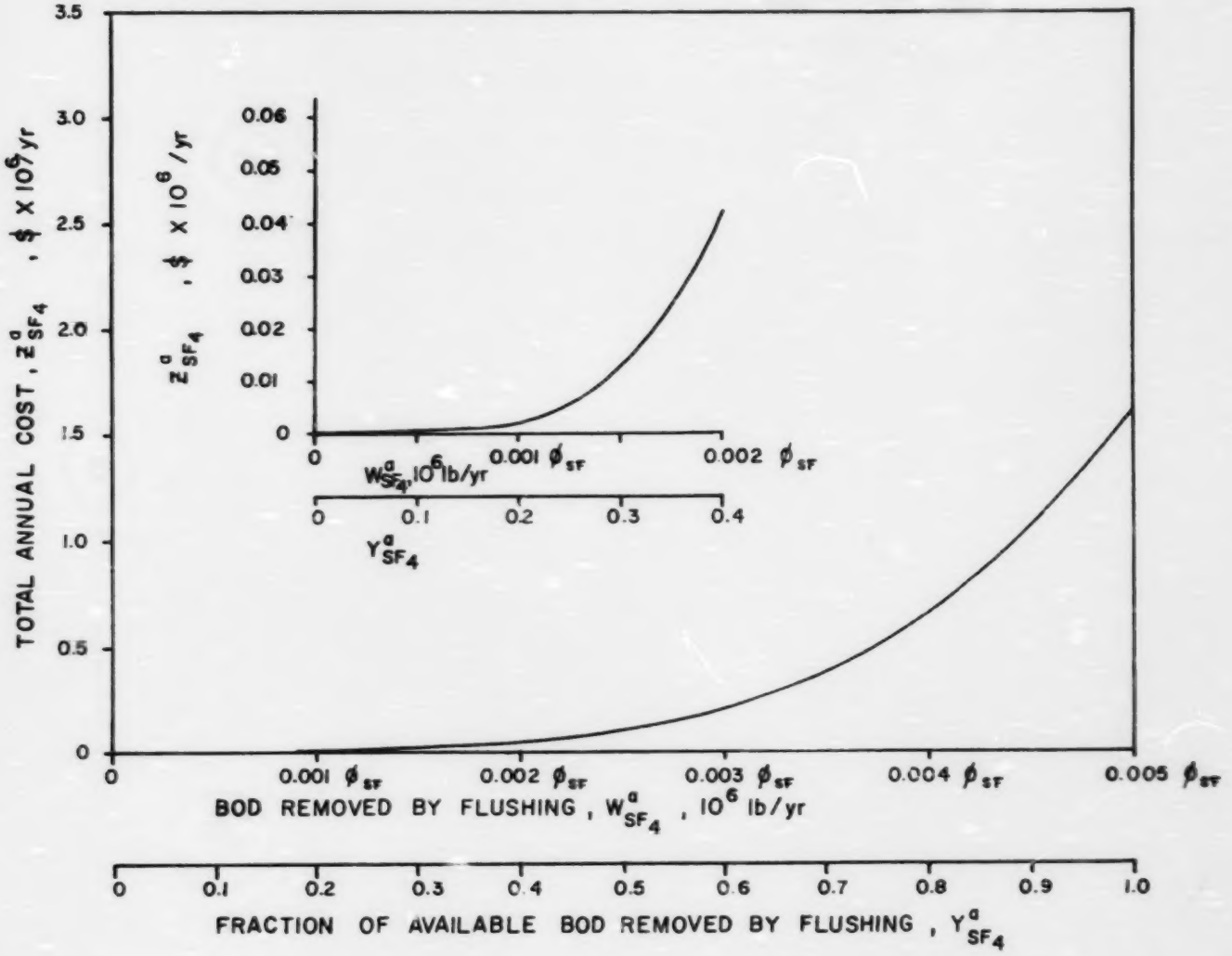

Figure B8. Total Cost Curve for Other Portion of Combined Sewered Areas, Sewer Flushing

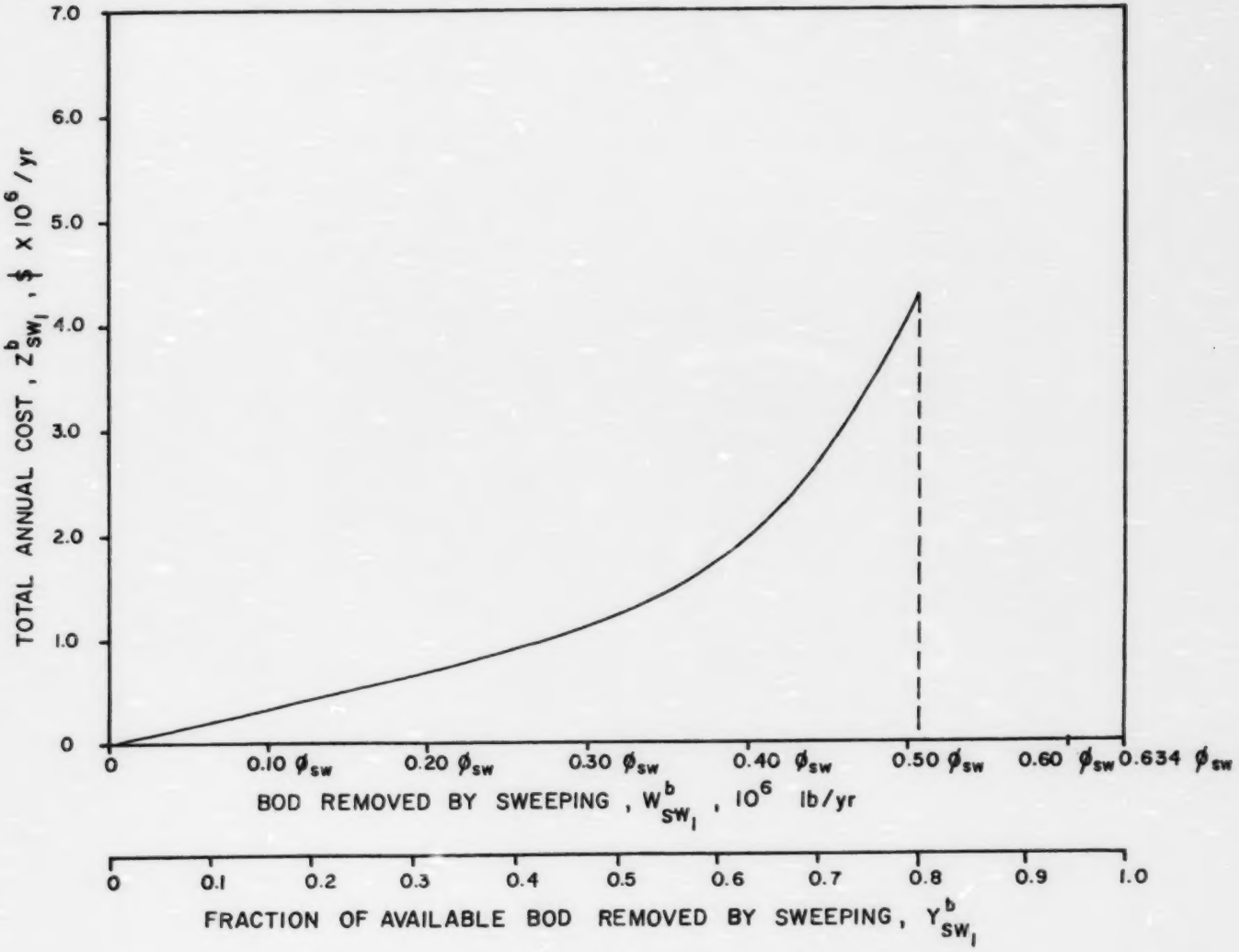

Figure B9. Total Cost Curve for Residential Portion of Storm Sewered Areas, Street Sweeping

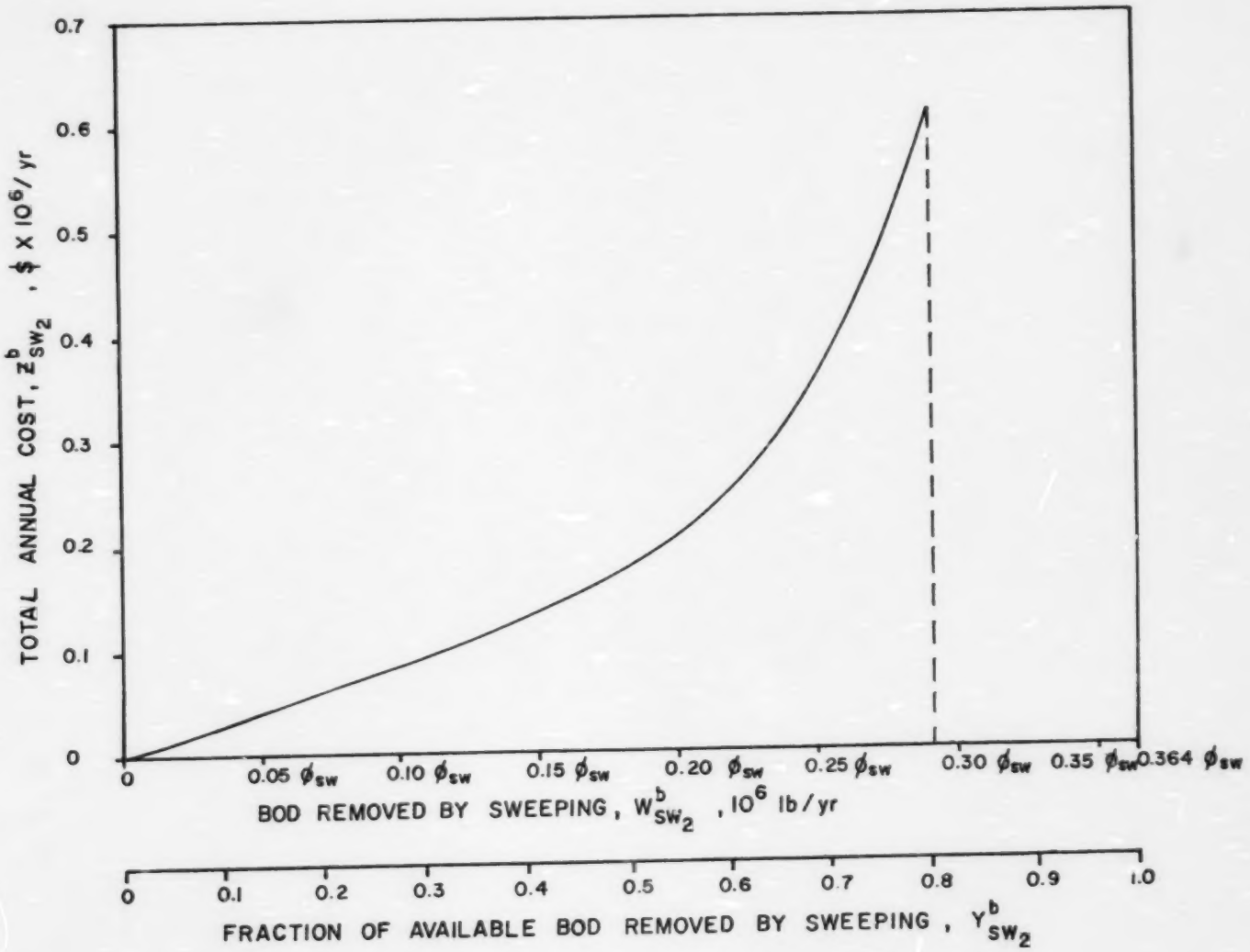

Figure B10. Total Cost Curve for Commercial Portion of Storm Sewered Areas, Street Sweeping

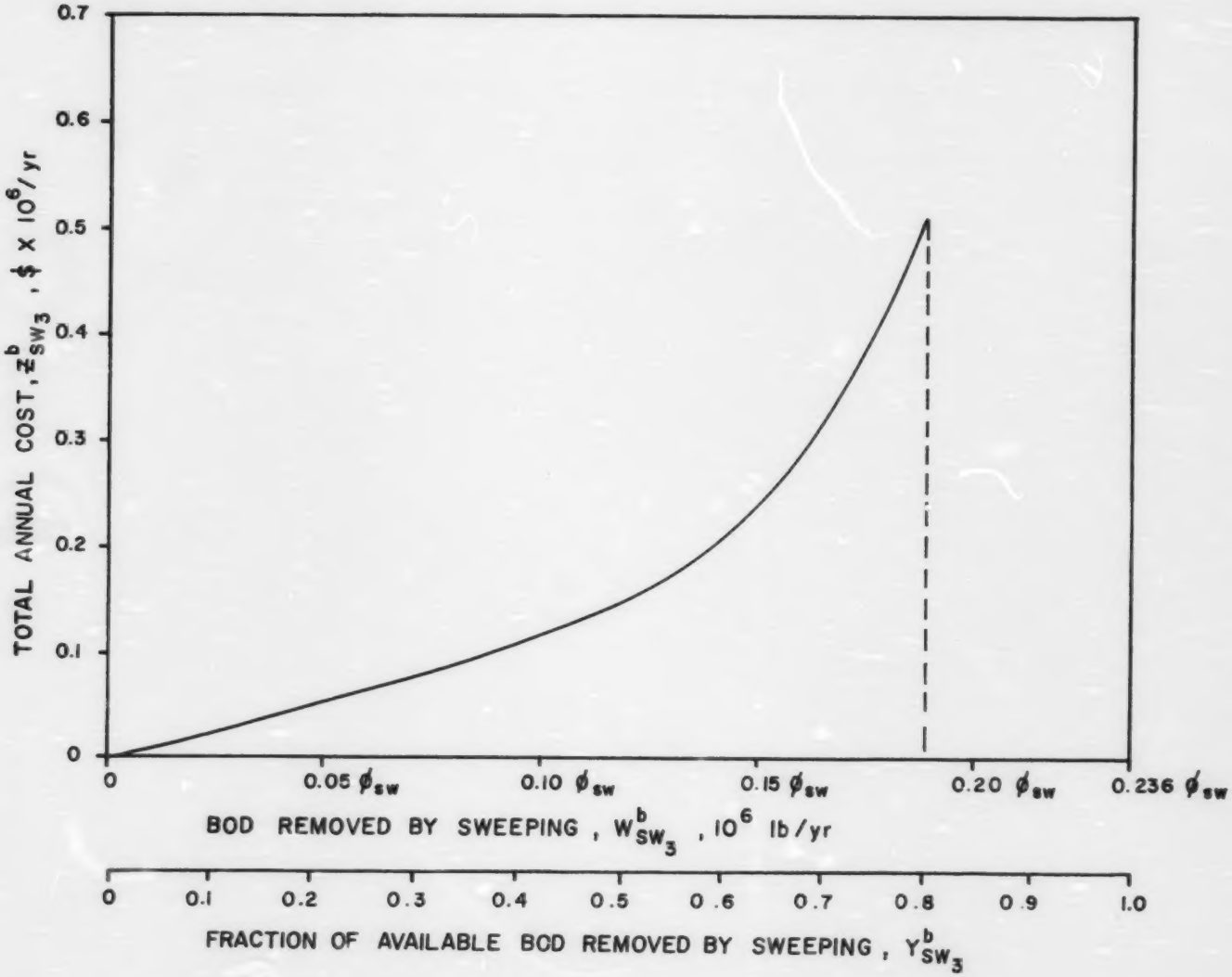

Figure B11. Total Cost Curve for Industrial Portion of Storm Sewered Areas, Street Sweeping

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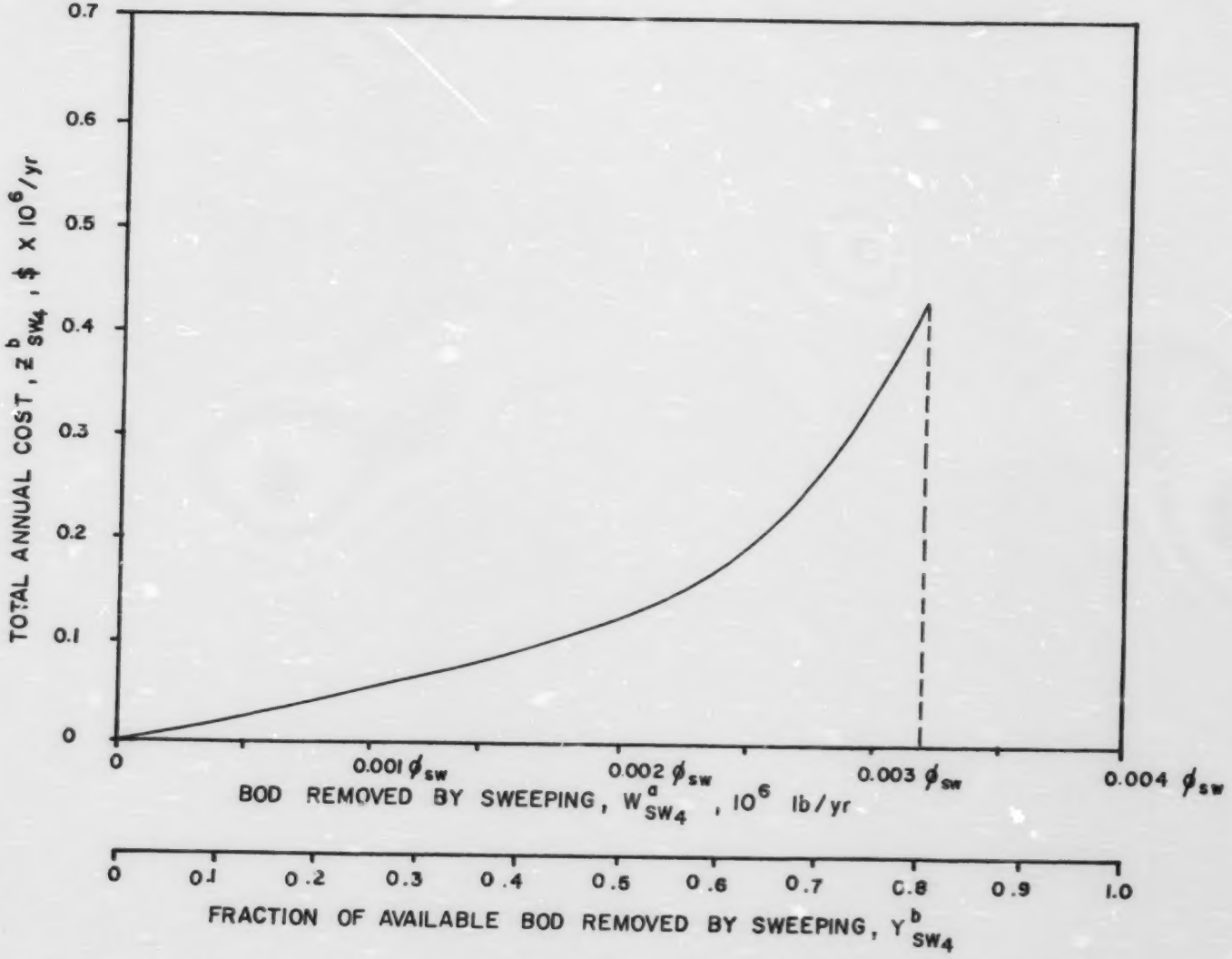

Figure B12. Total Cost Curve for Other Portion of Storm Sewered Areas, Street Sweeping

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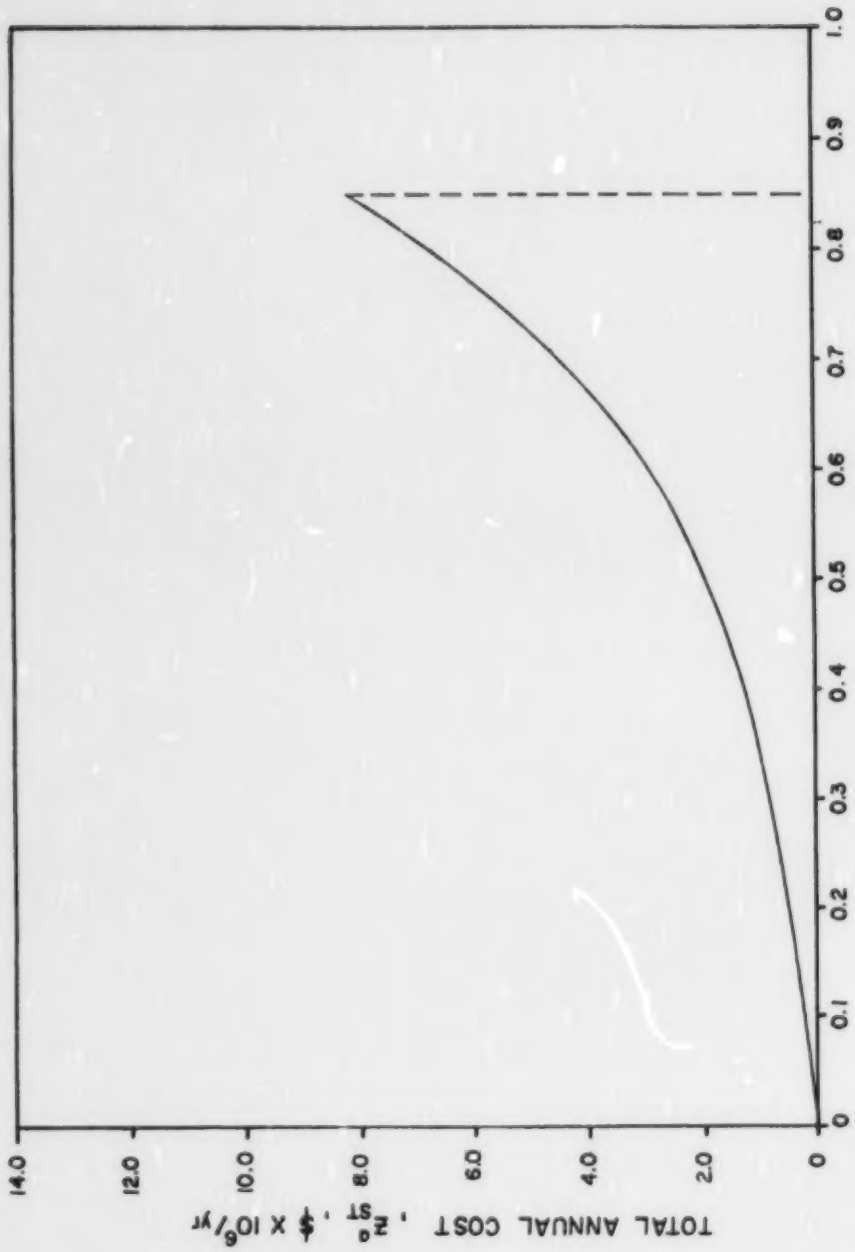

Figure B13. Total Cost Curve for Storage-Treatment, Combined Areas

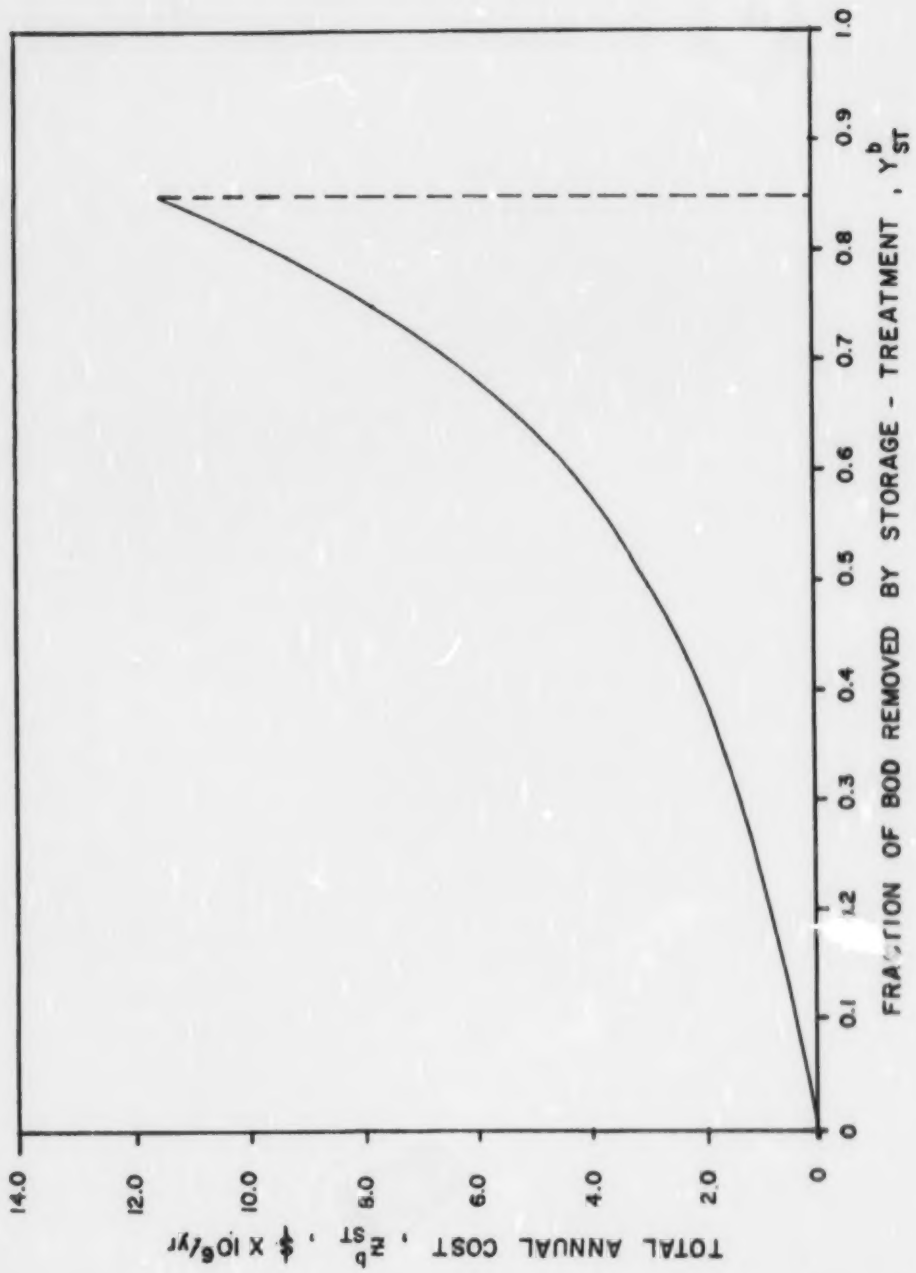

Figure B14. Total Cost Curve for Storage-Treatment, Storm Areas

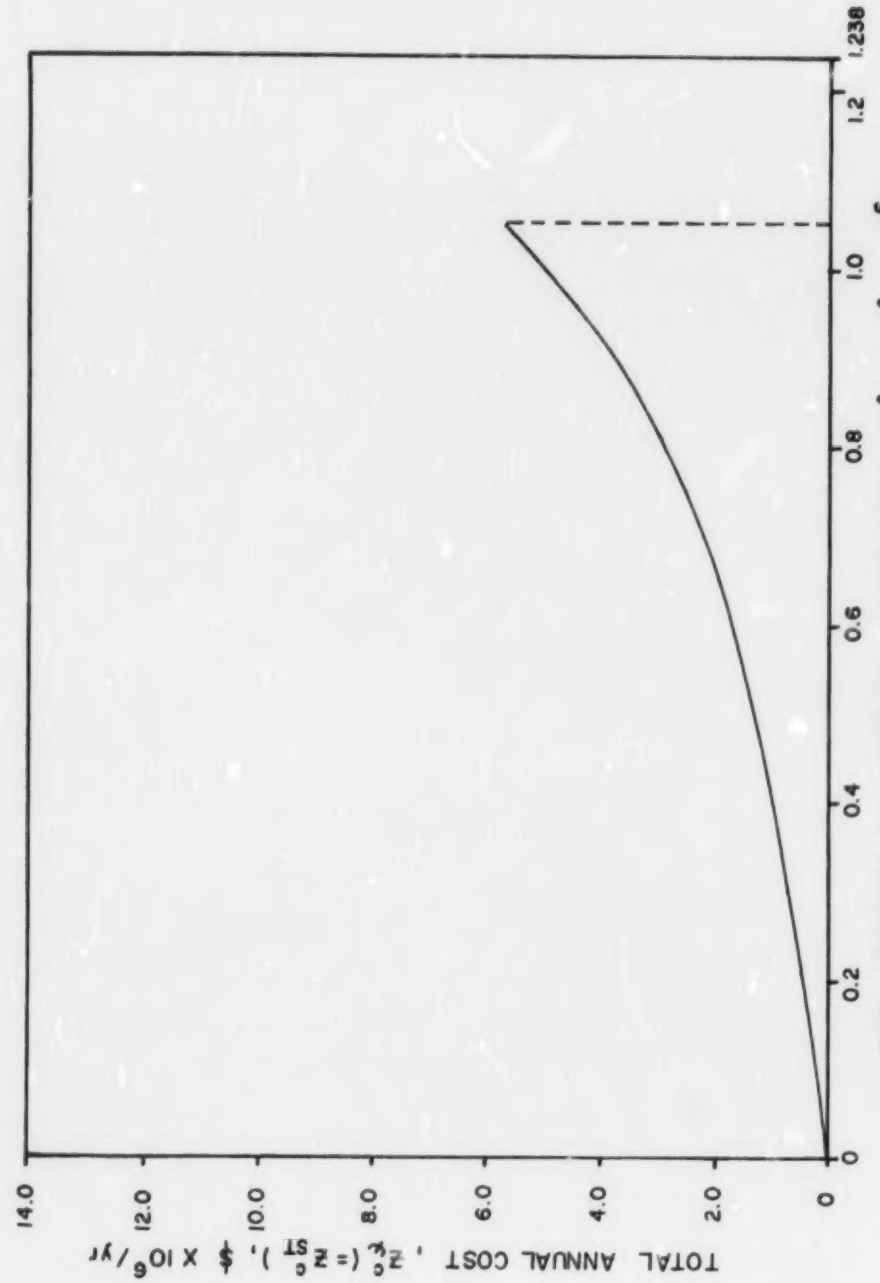

Figure B15. Total Cost Curve for all Options (Storage-Treatment), Unsewered Areas

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-77-083	2.
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See also EPA-600/2-76-275, Storm Water Management Model: Level I - Preliminary Screening Procedures

16. ABSTRACT

The original USEPA Storm Water Management Model (SWMM) provides a detailed simulation of the quantity and quality of stormwater during a specified precipitation event lasting a few hours. This model is widely used. However, it is too detailed for many purposes. Indeed, a wide range of evaluation techniques ranging from simple to complex procedures are needed. In particular, the 208 planning effort needs simplified procedures to permit preliminary screening of alternatives. In response to this need, four levels of stormwater management models are being prepared. This volume presents a "desktop" procedure to compare selected alternative control technologies.

A graphical procedure is described which permits the analyst to examine a wide variety of control options operating in series with one another or in parallel. The final result is presented as a control cost function for the entire study area which is the optimal (least costly) way of attaining any desired level of control. Given a specification regarding the desired overall level of control the user can determine the appropriate amount of each control to apply.

This methodology is applied to Anytown, U.S.A., a hypothetical community of 1,000,000 people. The results indicate the mix of treatment, storage, street sweeping, and sewer flushing which attains the specified pollution control level at minimum cost.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
*Storm sewers, *Water pollution, Control simulation, *Cost effectiveness, *Waste treatment, *Sewage treatment, *Surface water runoff, *Runoff, *Combined sewers, *Mathematical models, Storage tanks, Methodology, Economics, Flushing, Catch basins	Simplified evaluation, Sewer flushing, Street sweeping, Catch-basin cleaning	13B

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Areawide Assessment Procedures Manual
Appendix H
POINT SOURCE CONTROL ALTERNATIVES:
Performance and Cost

Prepared for
Municipal Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

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APPENDIX H

POINT SOURCE CONTROL ALTERNATIVES:

Performance and Cost

H.1 Introduction

Estimation of the monetary cost of the various control alternatives requires the ready availability of comprehensive construction and operating cost data. To facilitate use in a 208 program, these data must be in a convenient format applicable to the wide range of situations that may be encountered. The cost data should be useful to planners and engineers with varying degrees of technical background, and should be useful both for developing and for reviewing the costs associated with structural control alternatives.

Cost data presented in this appendix are generalized rather than site-specific, and are intended primarily for comparative analysis. Also, the data in this appendix represent a technology which is by no means static. Therefore, this information should be updated to reflect technological advances or other factors affecting comparative costs.

The user of this appendix is cautioned against treating any cost estimates based on the data contained herein as absolute. The estimates are valid only for comparative purposes, and even these comparisons must be performed with caution because of the possible differences in the reliability of the performance and cost information from various sources. There may be considerable difference between cost estimates for comparative purposes and the actual construction costs of facilities. Frequently, planners and engineers err in not emphasizing this fact enough to the local communities involved in the 208 program. The comparative numbers somehow become cast in stone during the planning phase. Later, during the implementation phase of the program, the communities express their concern when they find that the actual costs of implementation are vastly different than those implied by the comparative cost estimates.

H.2 Relative Reliability of Performance and Cost Information

Monetary-cost comparisons should not be the sole basis for selecting control alternatives, as discussed in Chapter 6; but, at some point in the selection process, the relative costs of various alternatives must be considered. Therefore, it is very important for the engineer or planner to understand the reliability of the information upon which the cost figures are based.

The reliability of performance data must also be considered, because this type of information frequently is the basis for determining the size of treatment units or other control devices needed for a particular control alternative. This section covers the use of the performance and cost information of Appendix G (Best Management Practices) and Appendix H (Point Source Control Alternatives), and provides a method for assuring adequate consideration of the relative reliability of the various applicable performance and cost information needed for comparison of applicable control alternatives.

The performance data and cost information in this and the Best Management Practices Appendix are utilized to determine the monetary cost of feasible control alternatives for addressing water quality problems in 208 planning areas. Performance data for a particular control alternative are compared to a required standard to assess the alternative's capability to meet the standard. Then the monetary costs of those alternatives which meet the performance requirements are determined by utilizing the cost curves. Since performance and cost information for one alternative may be based on much more extensive data and experience than the information for another alternative, the reliability of both the cost information and the performance information should be taken into account when considering relative cost and performance capabilities.

The reliability of information is especially important in developing, evaluating, and selecting control alternatives for areawide water quality management, because there are highly varying degrees of experience with the various control alternatives. For example, an abundance of cost figures and estimates are available to substantiate performance and cost curves for an activated sludge treatment plant. Less data and experience are available to substantiate performance and cost relationships for street sweeping as

an alternative in control of pollution from urban runoff. Even less data and experience may be available for various land management alternatives such as zoning. Although each of these three alternatives is known to be effective in reducing pollutant levels, determination of the best combination will require careful deliberation, good judgment, and full recognition of the reliability of each type of information at the time the decision is made.

The concept of "relative reliability" is presented here to aid the user of this manual in comparing the monetary cost of control alternatives. Five levels of relative reliability are used to identify the nature and extent of the experience and data upon which the cost and performance information is based:

- Level A indicates estimates based on detailed breakdowns of all pertinent cost elements and is supported by detailed engineering data. This level of reliability is always based on site-specific information. The relative reliability of information in this level is ± 15%. For example, facilities-planning estimates (Section 201 of P.L. 92-500) represent Level A information reliability.
- Level B indicates that the data and experience on a particular control alternative are sufficient only to establish a relationship, as expressed by a table of data or a single curve or family of curves. The relative reliability of information at this level is ± 30%. For example, general cost curves such as the wastewater treatment systems curves and process curves presented in Appendix H represent Level B information reliability.
- Level C indicates that the data and experience are sufficient only to establish a range of values for cost or performance. The relative reliability of information at this level is ± 50%. For example, street sweeping estimates, such as those in the Best Management Practices Appendix, represent Level C information reliability.
- Level D indicates that the data and experience are sufficient only to establish the relative order of magnitude of the cost and performance characteristics.

- Level E indicates that the data or experience is insufficient to establish any level of cost or performance estimate, or that site-specific factors are so critical to the performance and cost that a general estimate should not be made.

This manual does not present guidelines on the application of the relative reliability concept for particular situations. Rather, the application by the user will be a function of the control alternatives that are being compared, the closeness of the cost or performance estimates, the background of the user, the consequences of error, and other factors.

The "relative reliability" concept is introduced to emphasize to the user that comparisons of cost or performance estimates prepared using this manual are only as reliable as the lowest level of reliability assigned to the control alternatives being considered. The concept is particularly well suited to compare more traditional engineering approaches to load reduction with "emerging" non-structural control techniques whose costs and relative effectiveness have not been satisfactorily evaluated or sufficiently documented.

H.3 Cost Components

Information in a convenient format has been developed to provide a concise, yet complete, set of cost data that enable the user of the manual to produce cost estimates of adequate quality for use in comparing strategies in Area-wide Assessment Planning. Many sources were used in the development of the cost data, but in all cases the cost data were converted to a uniform basis. Where possible, these cost data were checked against actual construction costs.

The method used in developing the cost curves was to plot all available cost data uniformly, including actual construction costs. When differences in cost occurred, every effort was made to determine the reasons; and usually the significant differences were corrected, such as inclusion of buildings and pumps in some estimates and not in others. The curves included in this appendix were then fitted to these representative data.

Some of the costs presented in this appendix will be more reliable than others. Higher reliability costs generally occur where a large amount of historical

data exists, such as clarifiers and activated sludge. However, all cost data presented should be adequate to provide the user with the information needed to make judgments necessary in Areawide Assessment Planning.

Table H-1 provides the user with the general basis of all cost curves contained in this appendix.

H.3.1 Construction Costs

Construction-cost curves have been developed both for process components and for treatment systems. These construction-cost curves represent the cost of unit processes or treatment systems for a wide capacity range. Specific items not included in the construction cost are:

1. Land Costs (except land application and landfill).
2. Site Work.
3. Piping.
4. Electrical Work.
5. Engineering and Construction Supervision.
6. Project Contingencies.
7. Miscellaneous Structures.

The additional costs for Items 1 through 6 are generally represented as a percentage of the installed construction cost of the components specific to the unit or system being evaluated for comparative cost estimates of the type generally developed by using these curves. Additional cost curves are included for Item 7 (Miscellaneous Structures) and should be included where appropriate. Note that the cost curves developed for municipal wastewater treatment systems (Figures H-2 through H-16) already include the costs for miscellaneous structures. Table H-2 presents a general format for identifying the costs, with representative percentages for the items indicated. Land costs depend on local conditions and should be developed for each individual case. However, it should be noted that development of land costs, except in land application and land disposal of sludge, may not be necessary for comparison purposes. Most alternatives will have similar land requirements.

TABLE H-1

GENERAL COST AND DESIGN BASIS FOR COST CURVES

Basis of Costs

1. ENR = 2475, September 1976

2. Labor rate, including fringe benefits = $7.50/hr

   Note: Labor costs are based on a man-year of 1,500 hours. This represents: a 5-day work week; an average of 29 days for holidays, vacations, and sick leave; and 6½ hours of productive work time per day.

3. Energy Costs

a.	Electric Power	=	$0.02/kwh
b.	Fuel Oil	=	$0.37/gallon
c.	Gasoline	=	$0.60/gallon

4. Land = $1,000/acre

5. Chemical Costs

a.	Liquid Oxygen		=	$65/Ton
b.	Methanol		=	$0.50/gallon
c.	Chlorine	150-lb cylinder	=	$360/Ton
		1-ton cylinder	=	$260/Ton
		Tank Car	=	$160/Ton
d.	Quicklime		=	$25/Ton
e.	Hydrated Lime		=	$30/Ton (as CaO)
f.	Polymer (Dry)		=	$1.50/lb
g.	Ferric Chloride		=	$100/Ton
h.	Alum		=	$72/Ton
i.	Activated carbon (granulated)		=	$0.50/lb
j	Sulfuric Acid (66° Be')		=	$50/Ton
k.	Sodium hexametaphosphate		=	$0.25/lb
l.	SO_2	150-lb cylinders	=	$450/Ton
		1-Ton cylinder	=	$215/Ton
		Tank Car	=	$155/Ton

Design Basis

1. Construction costs and operation and maintenance costs are based on design average flow unless otherwise noted.

2. Operation and maintenance costs include:

   a. Labor costs for operation, preventive maintenance, and minor repairs.
   b. Materials costs to include replacement parts and major repair work (normally performed by outside contractors).
   c. Chemical costs.
   d. Fuel costs.
   e. Electrical power costs.

3. Construction costs do not include external piping, electrical, instrumentation, site work, contingency, or engineering and fiscal fees.

TABLE H-2

DEVELOPMENT OF CAPITAL COSTS

Component Installed Construction Costs				
			$_____	
(Unit processes specific to each Cost Estimate)			$_____	
Misc. Structures (Figure H-29)*			$_____	
Subtotal 1				$_____
	Avg.	Range**		
Piping	10%	8-15%	$_____	
Electrical	8%	5-12%	$_____	
Instrumentation	5%	3-10%	$_____	
Site Preparation	5%	1-10%	$_____	
Subtotal 2				$_____
Engineering and Construction -Supervision @ 15%	***		$_____	
Contingencies @ 15%	***		$_____	
TOTAL CAPITAL COST				$_____

*Not to be included when municipal wastewater treatment system or wet weather treatment process curves are used. These include miscellaneous structures in their construction costs.

**Range due to level of complexity, degree of instrumentation, subsoil conditions, configuration of site, etc.

***Percentage of Subtotal 2.

All construction costs have been indexed to September, 1976. To adjust for other time periods, appropriate cost indexes, such as those in the following list, should be used where appropriate:

- ENR Building Cost Index - appears weekly in Engineering News Record, McGraw-Hill, Inc.
- ENR Construction Cost Index - appears weekly in Engineering News Record, McGraw-Hill, Inc.
- EPA Treatment Plant and Sewer Construction Cost Index - appears monthly in the WPCF Journal.
- BLS Labor Cost Index - appears monthly in Employment and Earnings, Bureau of Labor Statistics.
- BLS Wholesale Price Index - appears monthly in Wholesale Prices and Prices Indexes, Bureau of Labor Statistics.

To facilitate use of the cost data presented in this appendix, each construction-cost curve includes a summary of the design basis, assumptions, and cost basis. Representative assumptions were made for the cost-curve development, but these can be easily modified to reflect site-specific conditions.

A generalized adjustment factor can be used to develop costs for mass or hydraulic loading factors, detention times, periods of operation, or solids concentrations other than those shown as the design basis. The cost curves are entered at an effective flow (Q_E), where

$$Q_E = Q_{DESIGN} \times \text{Cumulative Adjustment Factor}$$

where:

$$Q_{DESIGN} = \text{the flow shown on the curve}$$

and

$$\text{Cumulative Adjustment Factor} = \frac{\text{Design Mass Loading}}{\text{New Mass Loading}} \times \frac{\text{Design Solids Concentration}}{\text{New Solids Concentration}} \times \frac{\text{Design Time Operation}}{\text{New Time of Operation}} \times \text{Etc.}$$

This generalized adjustment factor will permit development of costs for site specific situations not identical to the design basis used for development of the curves.

Ideally, the cost curves would have been developed to compare a design parameter such as Surface Area or Volume vs Cost rather than Plant Flow vs Cost. For the purposes of this appendix, however, the latter approach was selected to screen the many alternatives required in Areawide Assessment.

A common occurrence when developing comparative cost estimates for areawide assessment plans is considering upgrading and/or expanding existing facilities. Often there are many economies to be realized in this practice. However, there are also economic disadvantages that should not be overlooked. Some of the additional costs that are often associated with upgrading and/or expanding an existing facility include interface costs associated with connecting pieces of equipment together, additional costs incurred by the contractor due to working in and around process equipment and yard piping, and problems of interfacing with old or obsolete equipment. Obviously, the actual additional costs associated with upgrading and/or expanding existing facilities will vary considerably depending on plant layout, contractor experience, age of existing plant, and relative size of the upgrade and/or expansion. However, a review of plant upgrade and expansions did provide a trend which can be useful in developing construction costs. Figure H-1 provides an Upgrade/Expansion Factor. This factor represents a percentage increase to be applied to the construction cost of the Upgrade/Expansion Alternative. As the size of the upgrade/expansion increases, the construction cost approaches the cost of a new facility. However, as the size of the upgrade/expansion decreases, the factor increases.

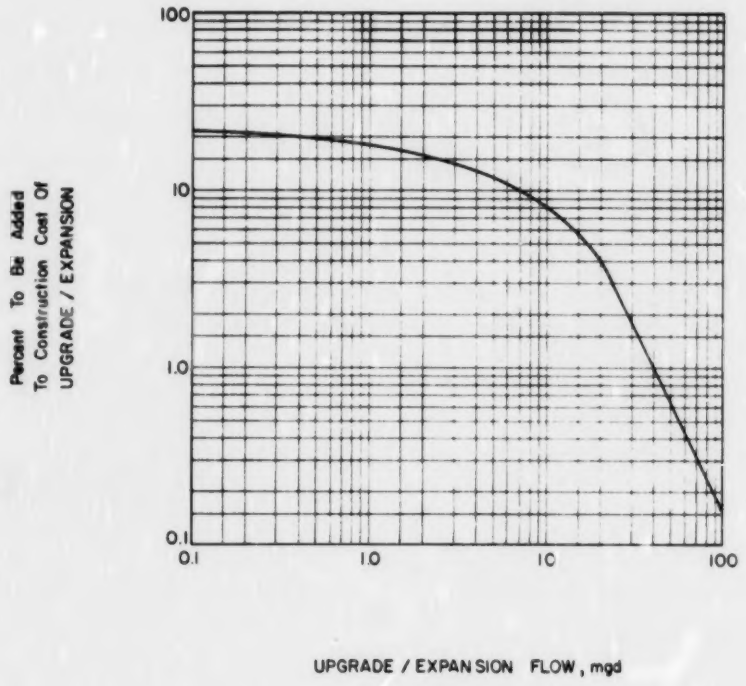
H.3.2 Operation and Maintenance Costs

Operation and maintenance costs consist of labor, material, energy, and chemical components. Each is detailed below. For each construction-cost curve, there is a corresponding O & M cost curve covering each of the O & M cost components and a total O & M cost.

FIGURE H-1

UPGRADING/EXPANSION FACTOR

FIGURE H-1 UPGRADING / EXPANSION FACTOR



H.3.2.1 Labor Costs

Labor costs include the manpower required to operate and maintain the facility or system, plus such support tasks as supervision and administration, clerical work, laboratory work, and yard work. Labor costs are based on a labor rate including fringe benefits of $7.50/hr; a man-year of 1,500 hours incorporating a five-day work week; an average of 29 days for holidays, vacations, and sick leave; and 6½ hours productive work time per day.

H.3.2.2 Material Costs

Material costs include the various materials required for routine maintenance of facilities. Examples are paint, grease, and replacement parts. Structural equipment (buildings, roads, and basins) generally has lower material costs than does mechanical equipment (pumps and aerators). Material costs have a base date of September, 1976. The wholesale price index should be used to adjust for other time periods.

H.3.2.3 Energy Costs

Each mechanical operation at a treatment facility, such as pumping, mixing, and aeration, consumes energy. The horsepower requirements have been converted into electrical units (KWH). A corresponding cost has been developed using a unit price of 2¢ per KWH. Adjustments to this unit cost for site-specific applications can be made by direct ratio.

Energy other than electrical is required for some processes (such as incineration). In these cases, the amount of energy (fuel) required was computed and a cost was determined on the basis of an assumed cost per unit; this assumed unit cost appears with the cost curves. Adjustments to this unit cost again may be made on a direct-ratio basis.

H.3.2.4 Chemical Cost

Various unit processes require chemicals. The quantities of chemicals required were based on assumed loading rates. The costs were then computed using a unit price for each chemical. The assumed unit chemical costs are included in Table H-1. Adjustments to the unit costs may be made by direct ratio within the same bulk quantity ranges.

H.4 Cost Format

The cost data in this appendix are presented in a format designed to facilitate use at the various levels of the planning process. The general presentation of the cost data is as follows:

- Treatment System Performance Matrix
  - Table H-3. Provides selected Municipal Wastewater Treatment Systems that will achieve varying degrees of treatment.
- Municipal Wastewater Treatment Systems: Performance and Costs
  - Figures H-2 through H-16, Section H.6
- Wet-Weather Treatment Processes: Costs
  - Figures H-17 through H-27, Section H.7
- Support Personnel: Costs
  - Figure H-28, Section H.8.1
- Miscellaneous Structures: Costs
  - Figure H-29, Section H.8.2
- Wastewater Treatment Processes: Costs
  - Figures H-30 through H-62, Section H.8.3
- Sludge Treatment and Disposal Processes: Costs
  - Figures H-63 through H-83, Section H.8.4
- Wastewater Transportation Methods: Costs
  - Figures H-84 and H-85, Section H.8.5
- Sludge Transportation Methods: Costs
  - Figures H-86 through H-90, Section H.8.6

The Treatment System curves will probably be most useful in the 208 process, because they provide a relatively quick and efficient means of developing comparative costs of various treatment facilities. If costs which are more specific to the site or facility involved are desired, the process curves in Sections H.7 and H.8 can be used to synthesize specific treatment systems as appropriate.

The process curves generally include individual unit processes, so that the system configuration for both treatment and sludge handling can be more flexible.

H.5 Treatment System Performance Matrix

The Treatment System Performance Matrix, Table H-3, links the point source load allocations and the Municipal Wastewater Treatment System cost curves.

Water quality throughout the planning period is defined by applying 20-year projected wastewater effluent characteristics from municipal wastewater treatment plants. Should an impact analysis indicate unacceptable stream water quality with these effluent characteristics, additional treatment would be required. The wastewater allocation needed to meet the water quality objectives establishes the effluent restrictions and, therefore, the required level of treatment. The control level refers to the projected effluent characteristics. Comparing these requirements to the Treatment System Performance Matrix indicates the system curve that most closely approximates the desired level of control. This should be done with caution because, when using the matrix, the system selected will be controlled by a single parameter. For example, System 11 may be required to meet the desired nitrogen level; therefore, total nitrogen is the controlling parameter. In order to achieve the required removal of this pollutant, System 11 might remove more BOD_5 than necessary. If this type of situation appears extreme, the user should evaluate the configuration of the required system to determine if the imbalance is unavoidable. If the manual user can conceive an alternative system that will produce a more balanced effluent with respect to the required effluent objective, then a new system curve should be developed from the component curves (Sections H.7 and H.8). In the foregoing example, a treatment system consisting of System 5 with the addition of breakpoint chlorination may provide a more cost-effective alternative to System 11. Should this be the case, the user of the manual can develop his own systems curves on the forms provided. The component municipal treatment process cost curves will provide the basis for the hybrid treatment system curves. The system configuration should be developed and the cumulative costs developed from the component municipal treatment process curves. The cumulative costs may be plotted on the forms provided.

TABLE H-3

TREATMENT SYSTEM PERFORMANCE MATRIX

System Number	Figure No	EFFLUENT CHARACTERISTICS							Description of System
		BOD_5	TSS	COD	Total P	NH_3-N	NO_3-N	UOD[1]	
-	-	210	230	400	11	20	0	406	Raw Waste Characteristics
1	H-2	130	100	250	9	20	0	286	Primary
2	H-3	100	50	185	2	20	0	241	Primary and Metal Salt Addition ($FeCl_3$)
3	H-4	45	60	90	8	18	0	150	Primary and Trickling Filter
4	H-5	25	30	50	2	18	0	120	Primary and Trickling Filter with Metal Salt ($FeCl_3$)
5	H-6	20	20	45	7	17	0	107	Primary and Activated Sludge
6	H-7	15	15	35	2	17	0	100	Primary, Activated Sludge, Metal Salt (Alum)
7	H-8	10	20	35	8	2	18	24	Primary, Activated Sludge/Nitrification
8	H-9	10	20	45	8	1	1	20	Primary. Activated Sludge, Nitrification, Denitrification
9	H-10	10	10	45	1	2	18	24	Primary Metal Salt Addition (Alum), Activated Sludge/Nitrification Filtration
10	H-11	5	5	25	1	20	0	99	Preliminary, Two-Stage Lime, Filtration, Carbon Adsorption
11	H-12	5	5	30	0.5	1	1	12	Primary Metal Salt Addition (Alum), Activated Sludge, Nitrification, Denitrification, Polymer, Filtration
12	H-13	3	5	10	0.5	1	1	12	Primary Metal Salt Addition (Alum), Activated Sludge, Nitrification-Denitrification, Polymer, Filtration, Carbon Adsorption
13	H-14	20	20	45	7	17[2] 2[3]	0	107	Small-Flow Treatment Systems, i.e., Package Plants - Extended Aeration Plant 0.01-0.1 mgd; contact stabilization plant 0.1-1.0 mgd.
14	H-15	15	15	46	6	1.0	8	27	Oxidation Ditch; 0.05-10 mgd (designed for nitrogen removal)
15	H-16	-	-	-	-	-	-	-	Land Application

Note: Treatment systems 1-12 include disinfection, sludge handling, miscellaneous structures, and support personnel. Treatment Systems 13-15 DO NOT include sludge dewatering, miscellaneous structures and support personnel.

[1] UOD = Ultimate Oxygen Demand = $(1.5 \times BOD_5) + (4.57 \times NH_3\text{-}N)$

[2] Contact Stabilization.

[3] Extended Aeration.

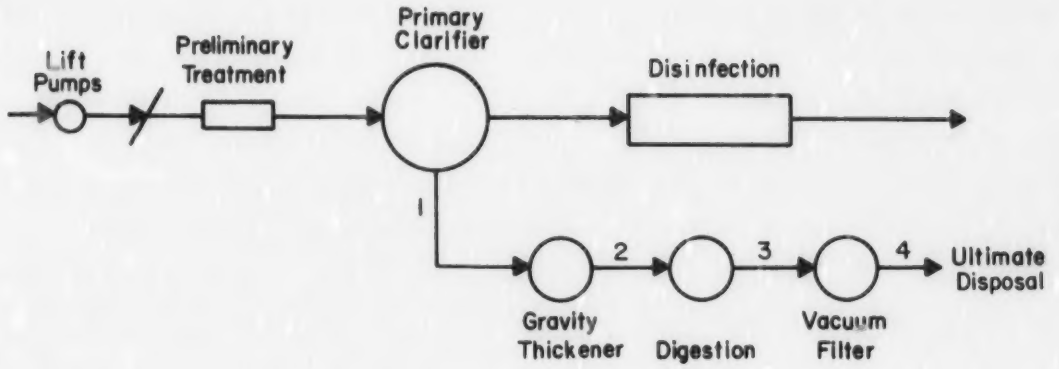
H.6 Municipal Wastewater Treatment Systems

Municipal wastewater treatment systems that will meet various effluent criteria are presented in the Treatment System Performance Matrix (Table H-3). These systems are not presented as a comprehensive list of the only technological methods available to meet the effluent criteria, but rather to provide the user of this manual with an expedient compilation of monetary costs for selected systems. Construction and operation & maintenance cost curves have been developed for each of these systems. The cost curves and related effluent quality, sludge audit, process, service life, design, and other data are presented in Figures H-2 through H-16.

Municipal Wastewater Treatment Systems:
Performance and Costs:

Figures H-2 through H-16

FIGURE H-2 TREATMENT SYSTEM 1-
PRIMARY TREATMENT



Processes Included: Lift Pumps, Preliminary Treatment, Primary Clarifiers, Chlorination, Gravity Thickener, Sludge Digestion, Vacuum Filters, Miscellaneous Structures, Support Personnel.

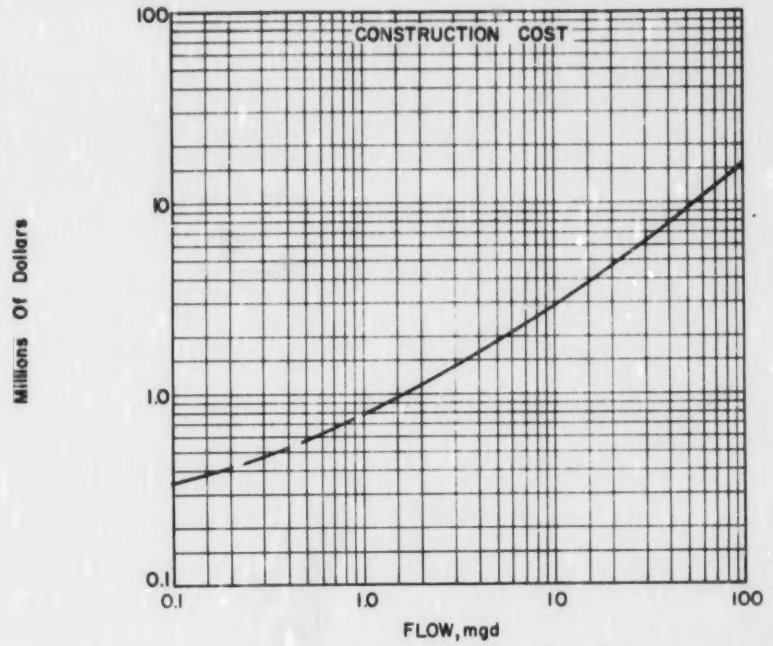
Wastewater Characteristics:	Influent	Effluent
BOD_5, mg/l	210	130
COD, mg/l	400	265
TSS, mg/l	230	100
Total-P, mg/l	11	9
NH_3-N, mg/l	20	20
NO_3-N, mg/l	0	0
UOD, mg/l	406	286

Sludge Audit:

Point No.	Sludge Quantity lbs/mg	Concentration %
1	1,080	4
2	1,080	8
3	540	4.5
4	540	20

Notes:
1. Dashed line on construction cost curve indicates size range of marginal applicability from a process and/or economic basis.
2. See individual treatment process curves for design basis of specific unit processes. (Adjustment factors should be used where applicable.)
3. Aerobic digestion at plant sizes less than 3 mgd; two-stage anaerobic digestion at plant sizes greater than 3 mgd.

FIGURE H-2 TREATMENT SYSTEM 1- PRIMARY TREATMENT



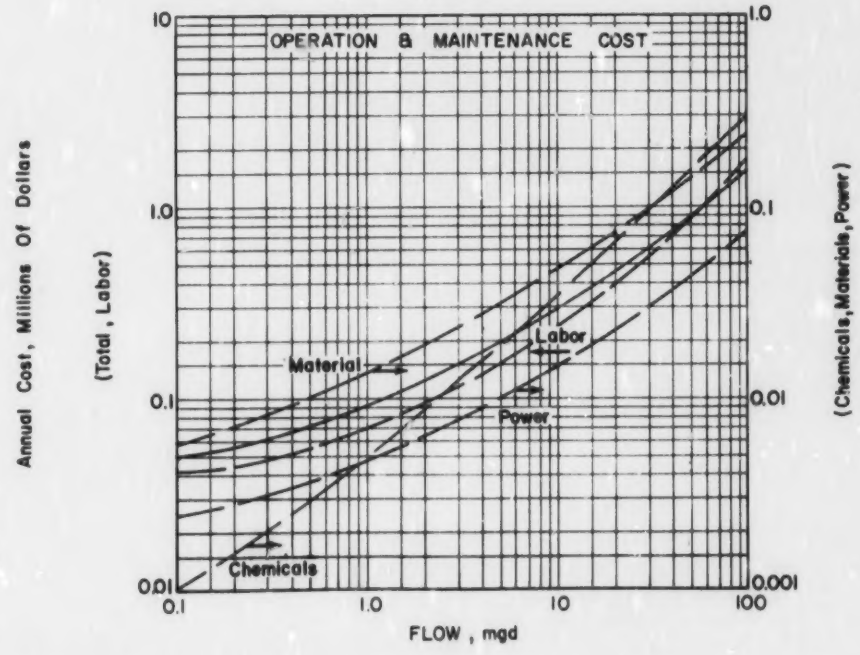
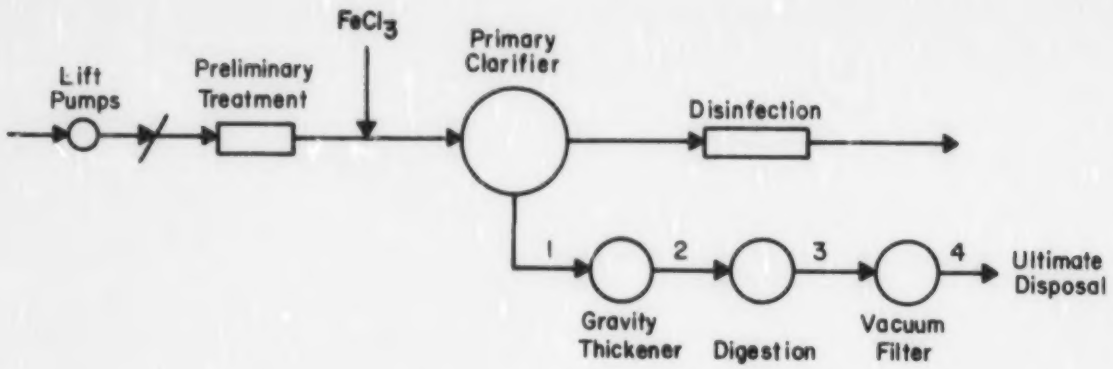


FIGURE H-3 TREATMENT SYSTEM 2-
PRIMARY TREATMENT WITH METAL-SALT ADDITION ($FeCl_3$)



Processes Included: Lift Pumps, Preliminary Treatment, Ferric Chloride Addition, Primary Clarifiers, Chlorination, Gravity Thickener, Sludge Digestion, Vacuum Filters, Miscellaneous Structures, Support Personnel.

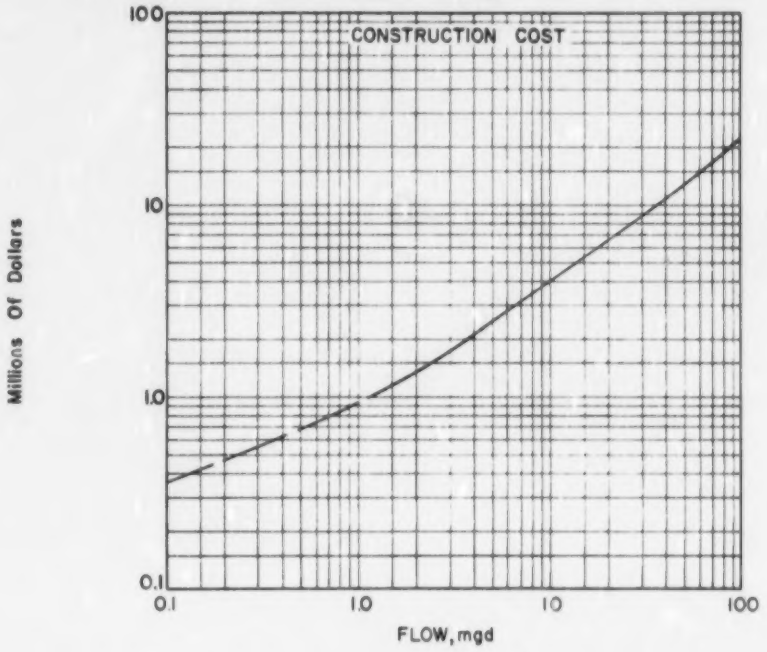
Wastewater Characteristics:	Influent	Effluent
BOD_5, mg/l	210	100
COD, mg/l	400	185
TSS, mg/l	230	50
Total-P, mg/l	11	2
NH_3-N, mg/l	20	20
NO_3-N, mg/l	0	0
UOD, mg/l	406	241

Sludge Audit:

Point No.	Sludge Quantity lbs/mg	Concentration %
1	2,160	2
2	2,160	4
3	1,410	3
4	1,410	20

Notes:
1. Dashed line on construction cost curve indicates size range of marginal applicability from a process and/or economic basis.
2. See individual treatment process curves for design basis of specific unit processes. (Adjustment factors should be used where applicable.)
3. $FeCl_3$ dosage at 100 mg/l.
4. Aerobic digestion at plant sizes less than 3 mgd; two-stage anaerobic digestion at plant sizes greater than 3 mgd.

FIGURE H-3 TREATMENT SYSTEM 2-
PRIMARY TREATMENT WITH METAL-SALT
ADDITION ($FeCl_3$)



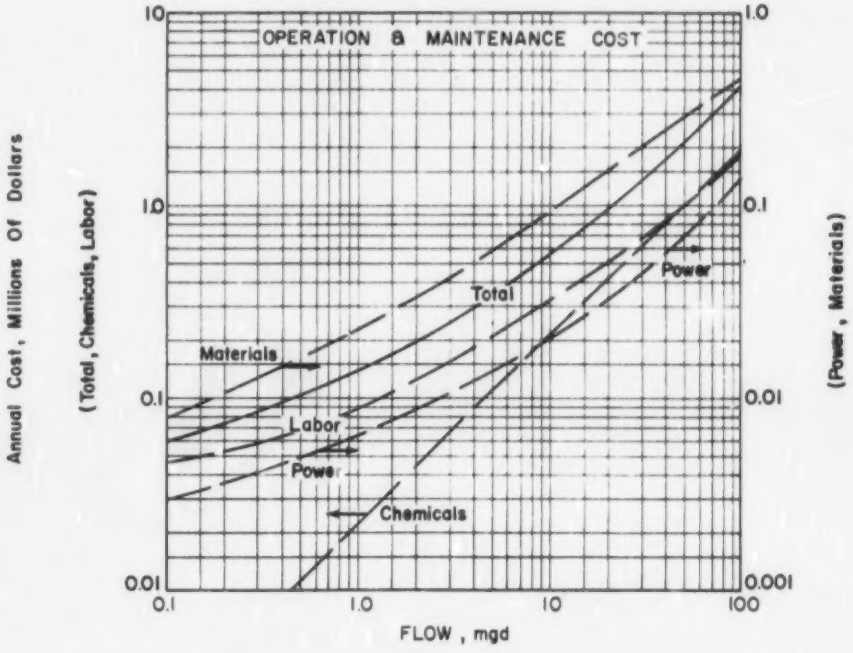
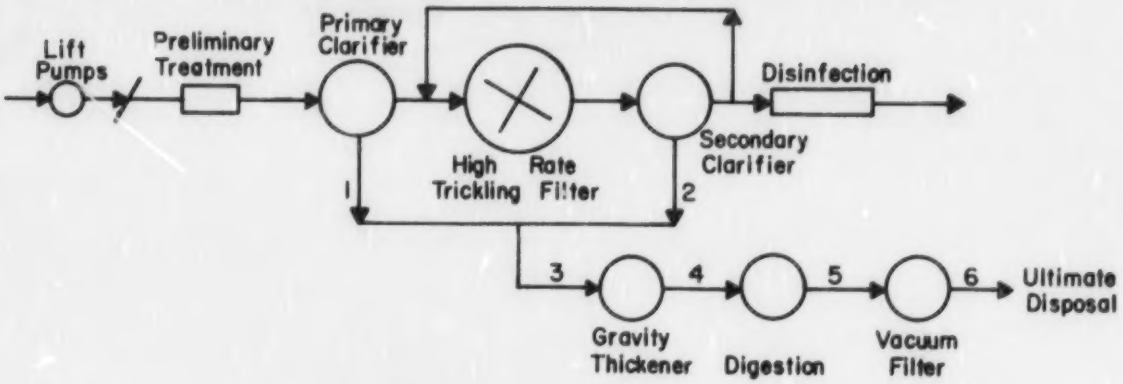


FIGURE H-4 TREATMENT SYSTEM 3- TRICKLING FILTER



Processes Included: Lift Pumps, Preliminary Treatment, Primary Clarifiers, High Rate Trickling Filter, Secondary Clarifiers, Chlorination, Gravity Thickener, Sludge Digestion, Vacuum Filters, Miscellaneous Structures, Support Personnel.

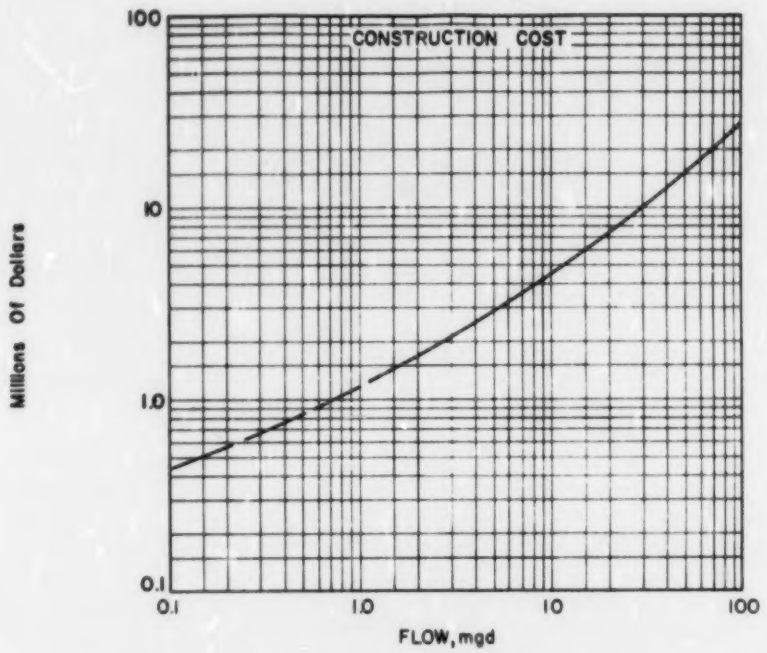
Wastewater Characteristics:	Influent	Effluent
BOD_5, mg/l	210	45
COD, mg/l	400	90
TSS, mg/l	230	60
Total-P, mg/l	11	8
NH_3-N, mg/l	20	18
NO_3-N, mg/l	0	0
UOD, mg/l	406	150

Sludge Audit:

Point No.	Sludge Quantity lbs/mg	Concentration %
1	1,080	4
2	450	3
3	1,530	4
4	1,530	5
5	765	3
6	765	20

Notes:
1. Dashed line on construction cost curve indicates size range of marginal applicability from a process and/or economic basis.
2. See individual treatment process curves for design basis of specific unit processes. (Adjustment factors should be used where applicable.)
3. Aerobic digestion at plant sizes less than 3 mgd; two-stage anaerobic digestion at plant sizes greater than 3 mgd.

FIGURE H-4 TREATMENT SYSTEM 3- TRICKLING FILTER



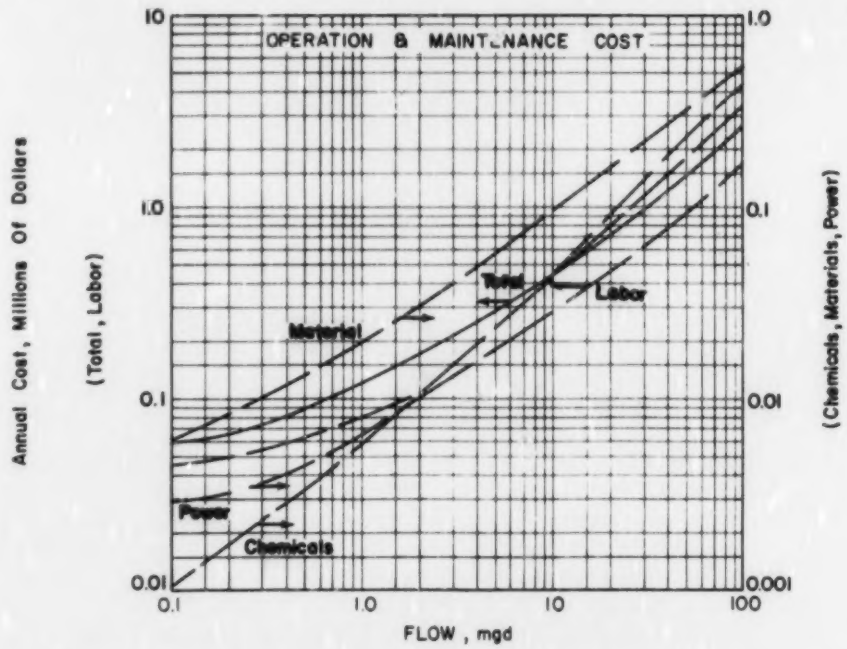
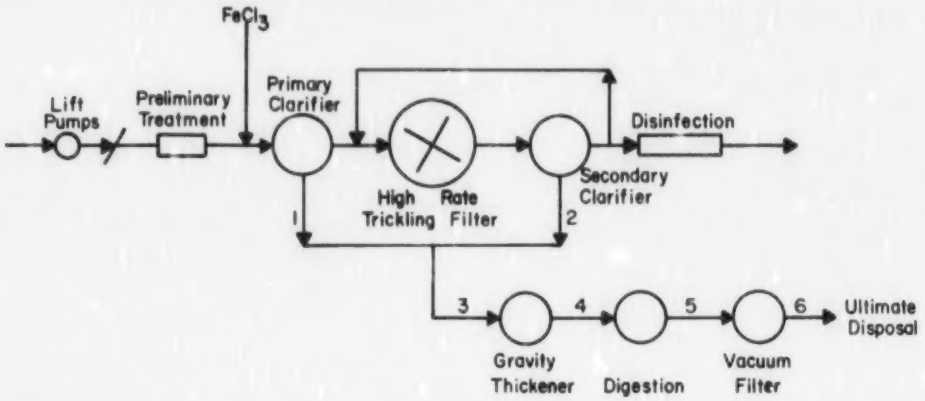


FIGURE H-5 TREATMENT SYSTEM 4-
TRICKLING FILTER WITH METAL- SALT ADDITION ($FeCl_3$)



Processes Included: Lift Pumps, Preliminary Treatment, Ferric Chloride Addition, Primary Clarifiers, High Rate Trickling Filters, Secondary Clarifiers, Chlorination, Gravity Thickener, Sludge Digestion, Vacuum Filters, Miscellaneous Structures, Support Personnel.

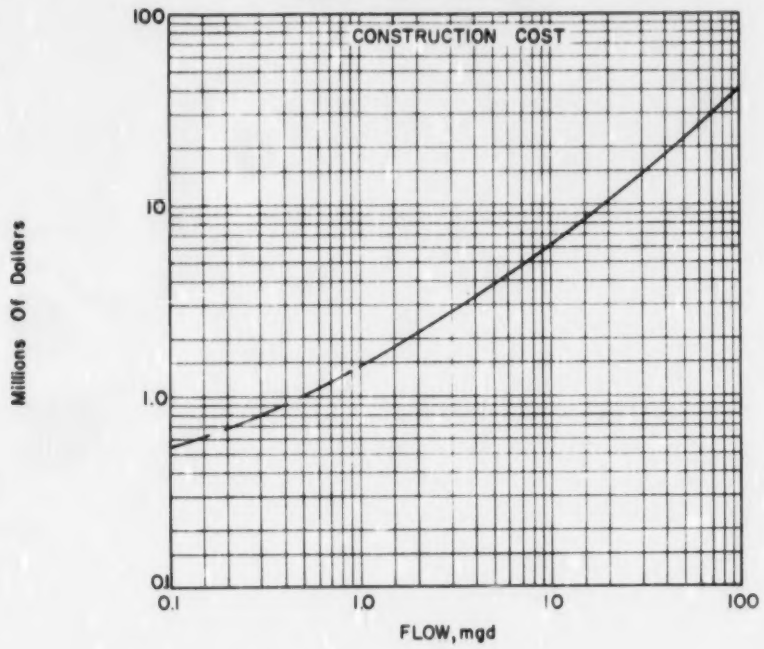
Wastewater Characteristics:	Influent	Effluent
BOD_5, mg/l	210	25
COD, mg/l	400	50
TSS, mg/l	230	30
Total-P, mg/l	11	2
NH_3-N, mg/l	20	18
NO_3-N, mg/l	0	0
UOD, mg/l	406	120

Sludge Audit:

Point No.	Sludge Quantity lbs/mg	Concentration %
1	2,160	2
2	330	3
3	2,490	2
4	2,490	4
5	1,580	3
6	1,580	20

Notes:
1. Dashed line on construction cost curve indicates size range of marginal applicability from a process and/or economic basis.
2. See individual treatment process curves for design basis of specific unit processes. (Adjustment factors should be used where applicable.)
3. $FeCl_3$ dosage at 100 mg/l.
4. Aerobic digestion at plant sizes less than 3 mgd; two-stage anaerobic digestion at plant sizes greater than 3 mgd.

FIGURE H-5 TREATMENT SYSTEM 4- TRICKLING FILTER WITH METAL-SALT ADDITION ($FeCl_3$)



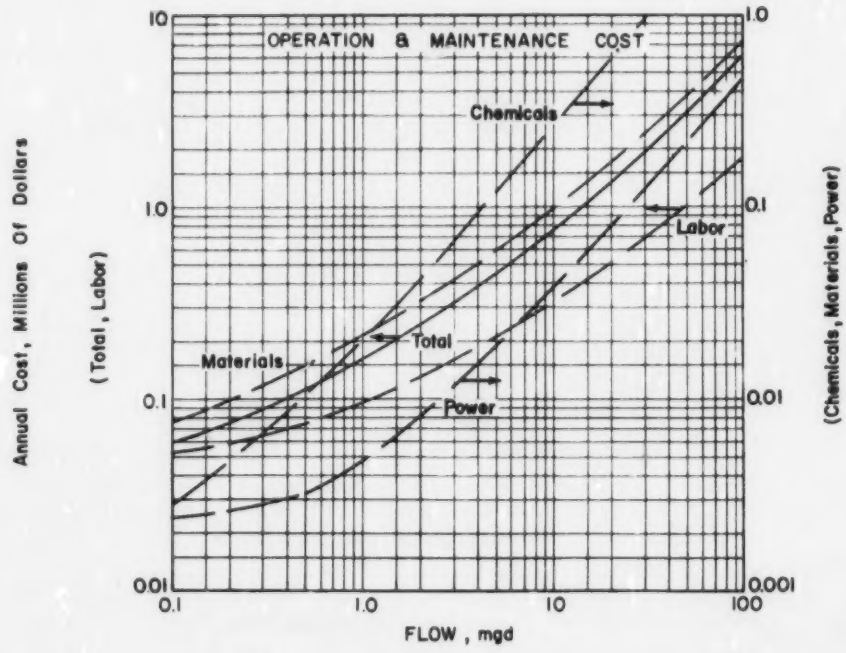
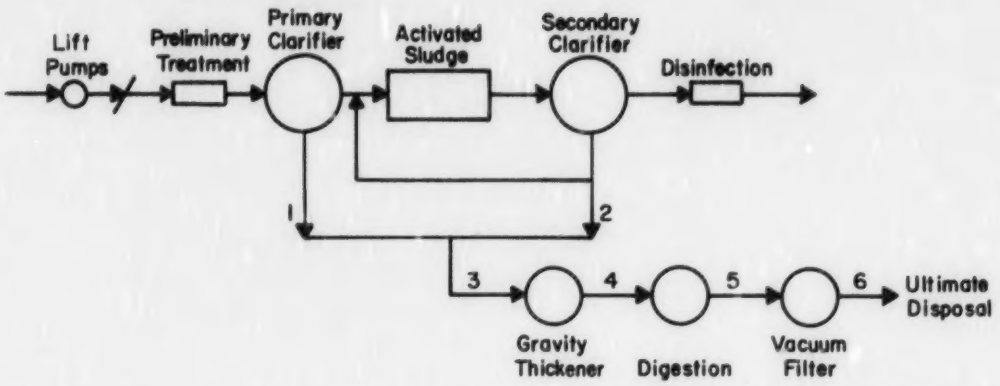


FIGURE H-6 TREATMENT SYSTEM 5-
ACTIVATED SLUDGE



Processes Included: Lift Pumps, Preliminary Treatment, Primary Clarifiers, Activated Sludge, Secondary Clarifiers, Chlorination, Gravity Thickener, Sludge Digestion, Vacuum Filters, Miscellaneous Structures, Support Personnel.

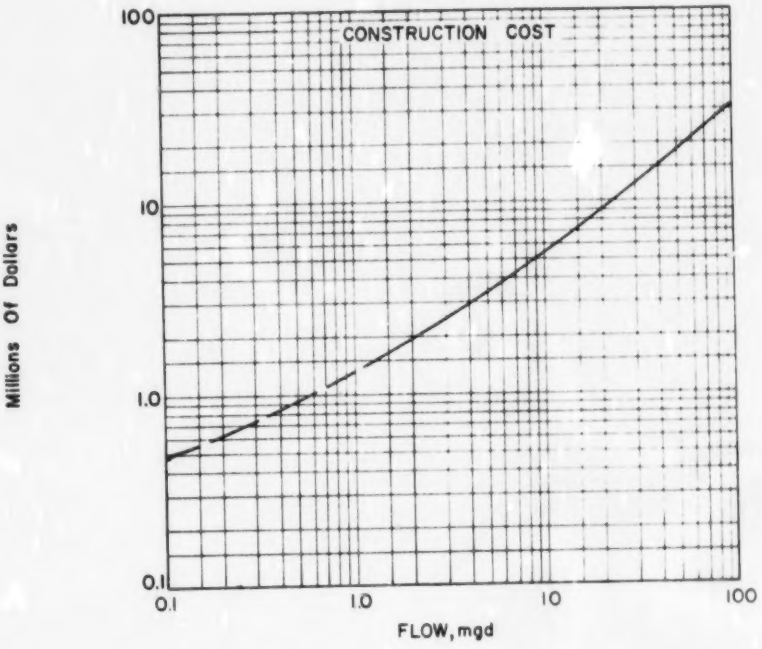
Wastewater Characteristics:	Influent	Effluent
BOD_5, mg/l	210	20
COD, mg/l	400	45
TSS, mg/l	230	20
Total-P, mg/l	11	7
NH_3-N, mg/l	20	17
NO_3-N, mg/l	0	0
UOD, mg/l	406	107

Sludge Audit:

Point No.	Sludge Quantity lbs/mg	Concentration %
1	1,080	4
2	820	0.8
3	1,900	2.6
4	1,900	8
5	950	5
6	950	20

Notes:
1. Dashed line on construction cost curve indicates size range of marginal applicability from a process and/or economic basis.
2. See individual treatment process curves for design basis of specific unit processes. (Adjustment factors should be used where applicable.)
3. Aerobic digestion at plant sizes less than 3 mgd; two-stage anaerobic digestion at plant sizes greater than 3 mgd.

FIGURE H-6 TREATMENT SYSTEM 5- ACTIVATED SLUDGE



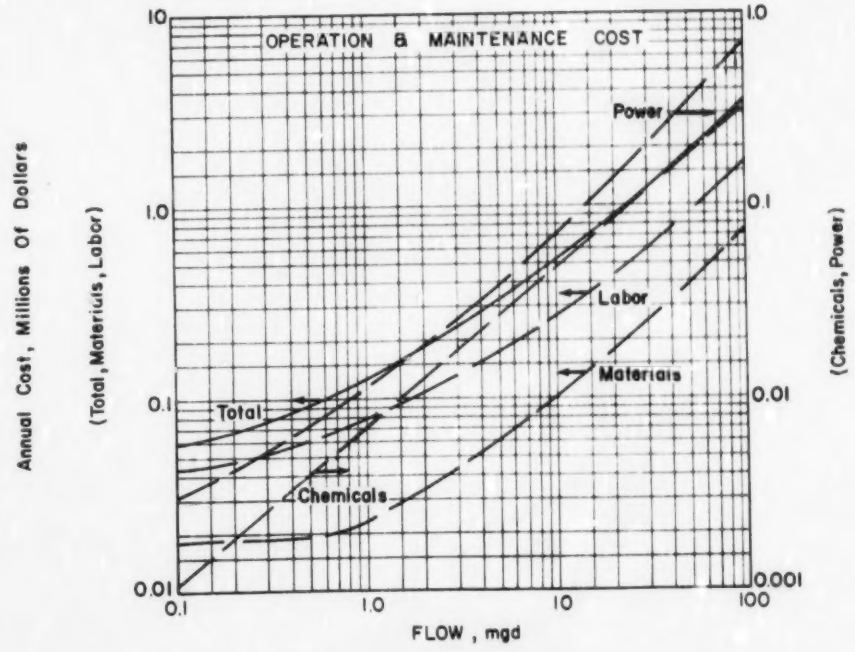
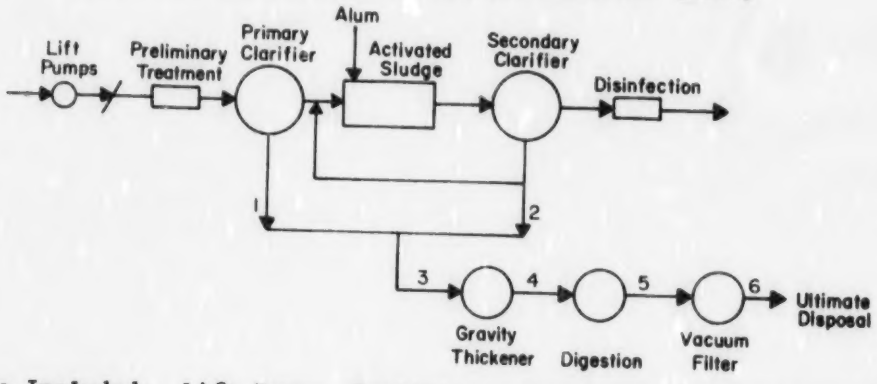


FIGURE H-7 TREATMENT SYSTEM 6-
ACTIVATED SLUDGE WITH METAL-SALT ADDITION (ALUM)



Processes Included: Lift Pumps, Preliminary Treatment, Primary Clarifiers, Alum Addition, Activated Sludge, Secondary Clarifiers, Chlorination, Gravity Thickener, Sludge Digestion, Vacuum Filters, Miscellaneous Structures, Support Personnel.

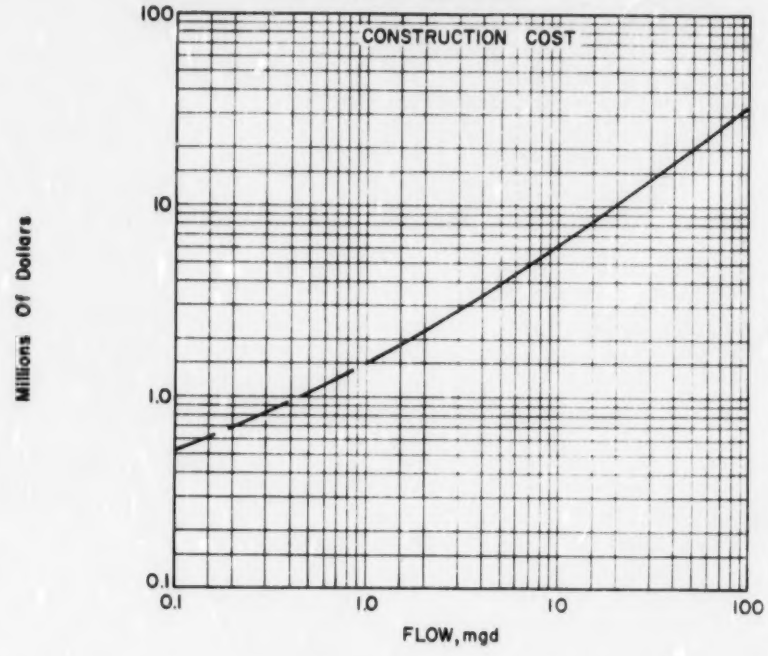
Wastewater Characteristics:	Influent	Effluent
BOD_5, mg/l	210	15
COD, mg/l	400	35
TSS, mg/l	230	15
Total-P, mg/l	11	2
NH_3-N, mg/l	20	17
NO_3-N, mg/l	0	0
UOD, mg/l	406	100

Sludge Audit:

Point No.	Sludge Quantity lbs/mg	Concentration %
1	1,080	4
2	1,150	0.8
3	2,230	2.3
4	2,230	6
5	1,280	3.5
6	1,280	20

Notes:
1. Dashed line on construction cost curve indicates size range of marginal applicability from a process and/or economic basis.
2. See individual treatment process curves for design basis of specific unit processes. (Adjustment factors should be used where applicable.)
3. Alum dosage at 100 mg/l.
4. Aerobic digestion at plant sizes less than 3 mgd; two-stage anaerobic digestion at plant sizes greater than 3 mgd.

FIGURE H-7 TREATMENT SYSTEM 6 - ACTIVATED SLUDGE WITH METAL-SALT ADDITION (ALUM)



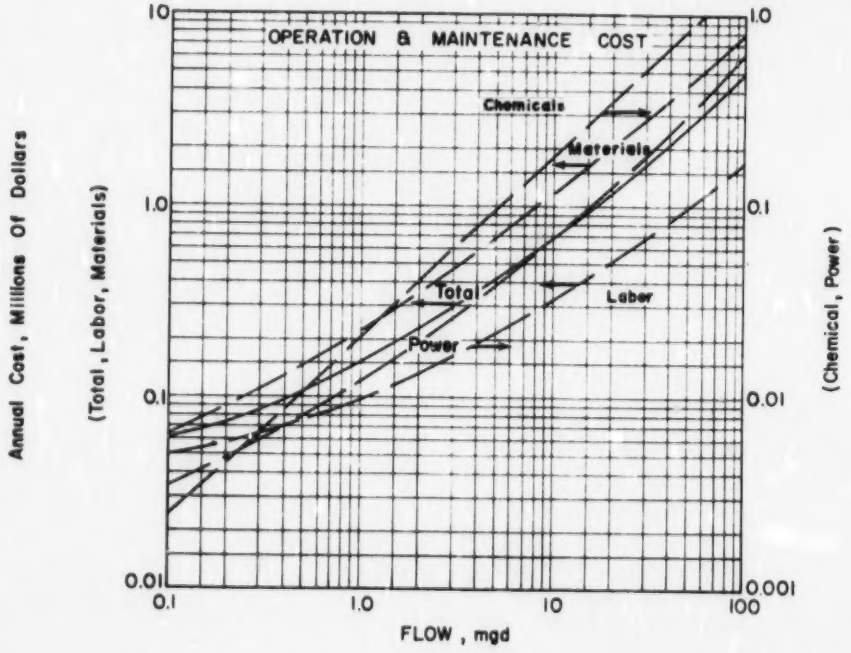
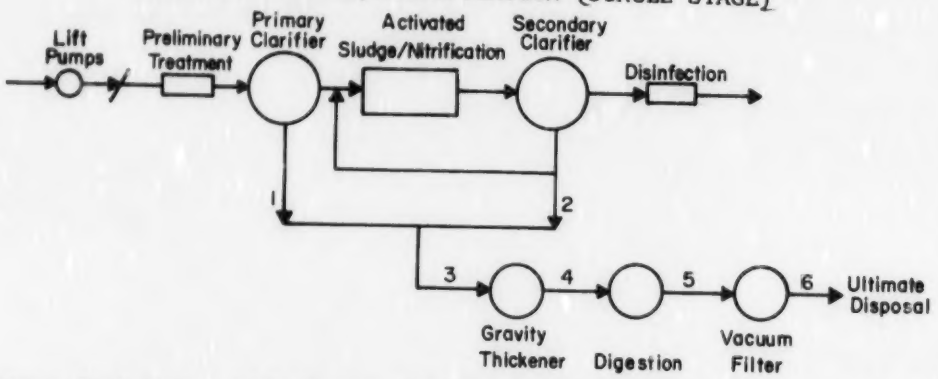


FIGURE H-8 TREATMENT SYSTEM 7-
ACTIVATED SLUDGE/NITRIFICATION (SINGLE STAGE)



Processes Included: Lift Pumps, Preliminary Treatment, Primary Clarifiers, Activated Sludge with Nitrification, Secondary Clarifiers, Chlorination, Gravity Thickener, Sludge Digestion, Vacuum Filters, Miscellaneous Structures, Support Personnel.

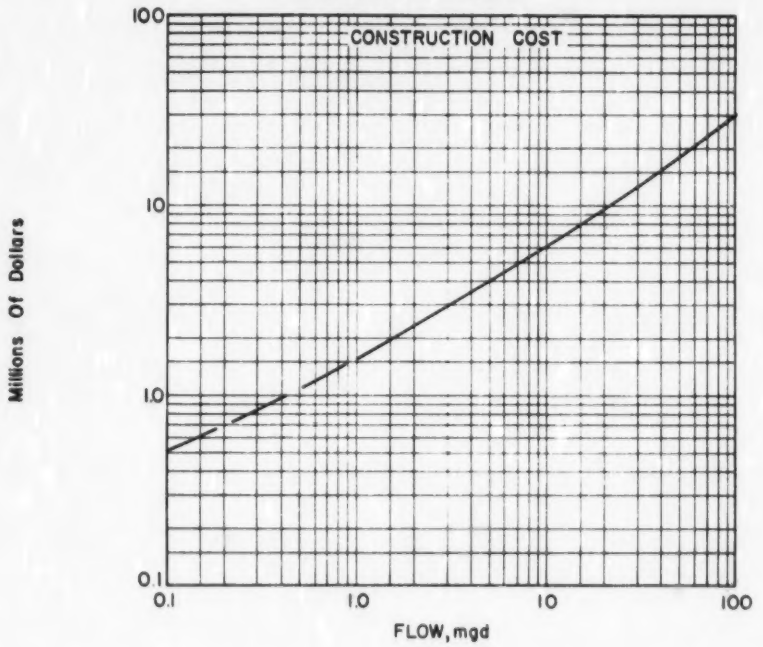
Wastewater Characteristics:	Influent	Effluent
BOD_5, mg/l	210	10
COD, mg/l	400	35
TSS, mg/l	230	20
Total-P, mg/l	11	8
NH_3-N, mg/l	20	2
NO_3-N, mg/l	0	18
UOD, mg/l	406	24

Sludge Audit:

Point No.	Sludge Quantity lbs/mg	Concentration %
1	1,080	4
2	820	0.8
3	1,900	2.6
4	1,900	4
5	950	2.5
6	950	20

Notes:
1. Dashed line on construction cost curve indicates size range of marginal applicability from a process and/or economic basis.
2. See individual treatment process curves for design basis of specific unit processes. (Adjustment factors should be used where applicable.)
3. Aerobic digestion at plant sizes less than 3 mgd; two-stage anaerobic digestion at plant sizes greater than 3 mgd.

FIGURE H-8 TREATMENT SYSTEM 7- ACTIVATED SLUDGE / NITRIFICATION (SINGLE STAGE)



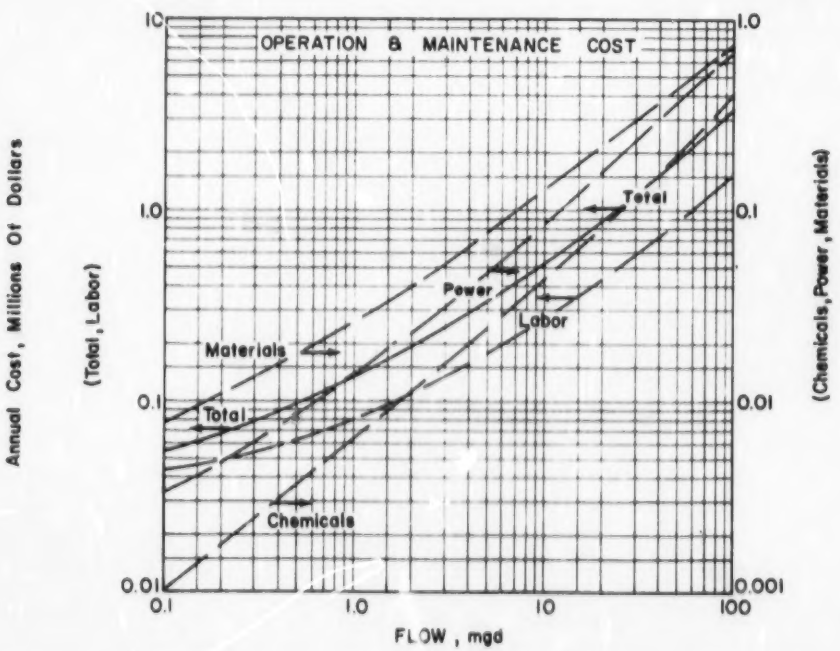
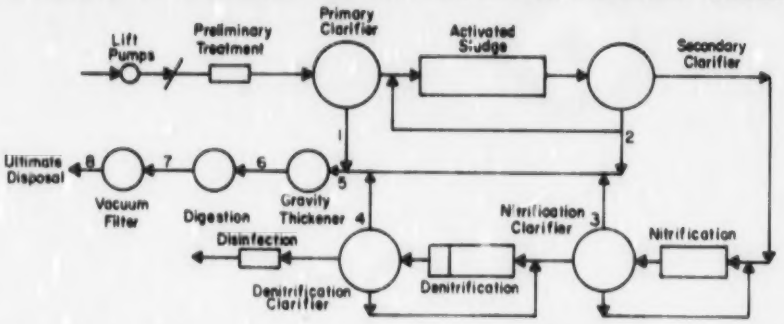


FIGURE H-9 TREATMENT SYSTEM 8-
ACTIVATED SLUDGE/NITRIFICATION/DENITRIFICATION (THREE STAGES)



Processes Included: Lift Pumps, Preliminary Treatment, Primary Clarifiers, Activated Sludge, Secondary Clarifiers, Nitrification, Denitrification, Chlorination, Gravity Thickener, Sludge Digestion, Vacuum Filters, Miscellaneous Structures, Support Personnel.

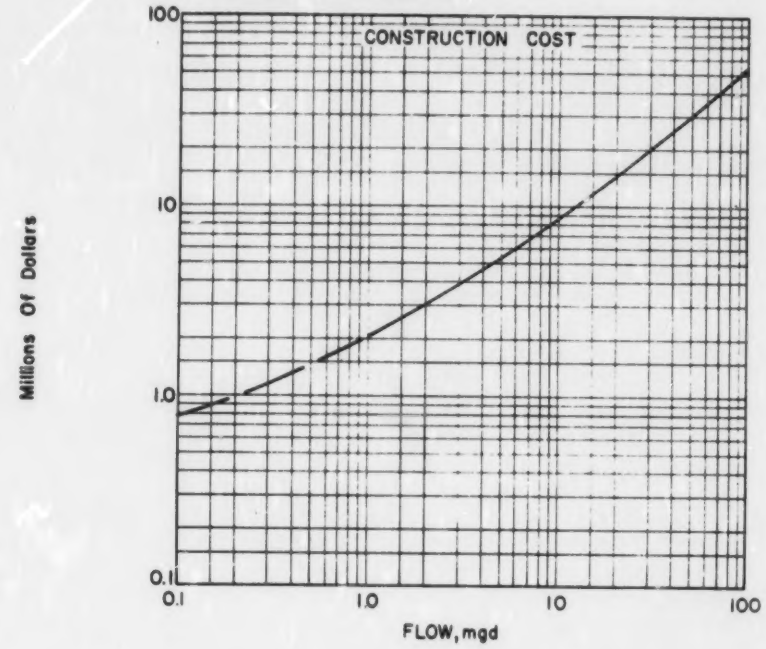
Wastewater Characteristics:	**Influent**	**Effluent**
BOD_5, mg/l	210	10
COD, mg/l	400	45
TSS, mg/l	230	20
Total-P, mg/l	11	8
NH_3-N, mg/l	20	1
NO_3-N, mg/l	0	1
UOD, mg/l	406	20

Sludge Audit:

Point No.	Sludge Quantity lbs/mg	Concentration %
1	1,080	4
2	720	0.8
3	100	0.8
4	280	0.8
5	2,180	2.4
6	2,180	4
7	1,090	2.5
8	1,090	20

Notes:
1. Dashed line on construction cost curve indicates size range of marginal applicability from a process and/or economic basis.
2. See individual treatment process curves for design basis of specific unit processes. (Adjustment factors should be used where applicable.)
3. Aerobic digestion at plant sizes less than 3 mgd; two-stage anaerobic digestion at plant sizes greater than 3 mgd.

FIGURE H-9 TREATMENT SYSTEM 8-
ACTIVATED SLUDGE/NITRIFICATION/DENITRIFICATION
(THREE STAGES)



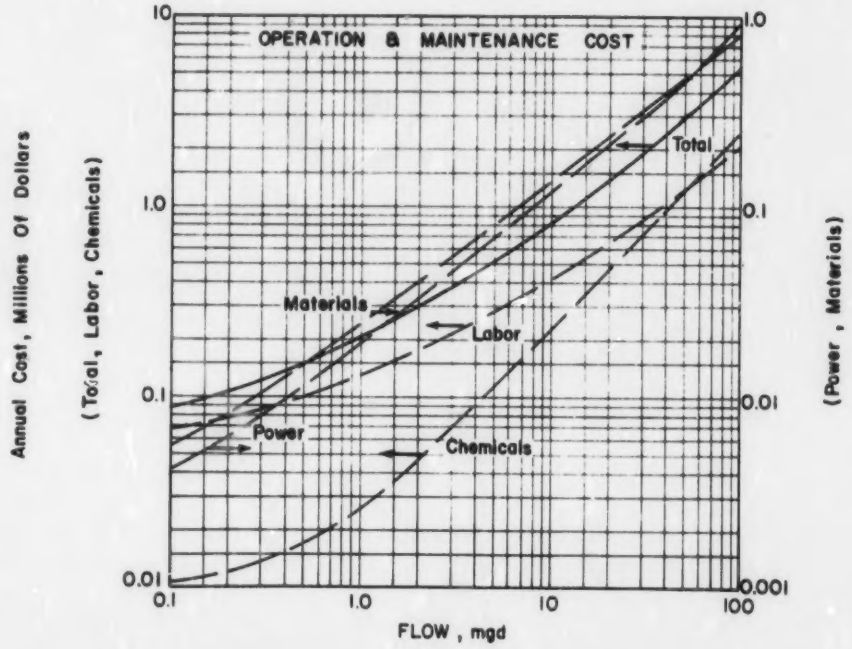
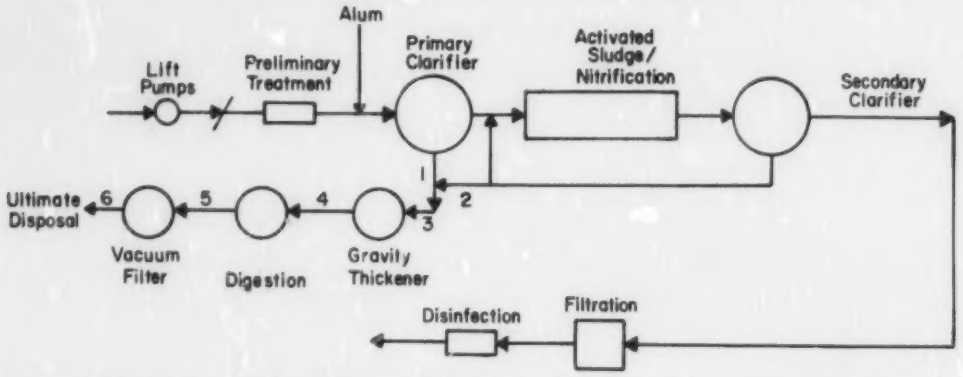


FIGURE H-10 TREATMENT SYSTEM 9-
ACTIVATED SLUDGE/NITRIFICATION - FILTRATION (WITH ALUM)



Processes Included: Lift Pumps, Preliminary Treatment, Alum Addition, Primary Clarifiers, Activated Sludge with Nitrification, Secondary Clarifiers, Filtration, Chlorination, Gravity Thickener, Sludge Digestion, Vacuum Filters, Miscellaneous Structures, Support Personnel.

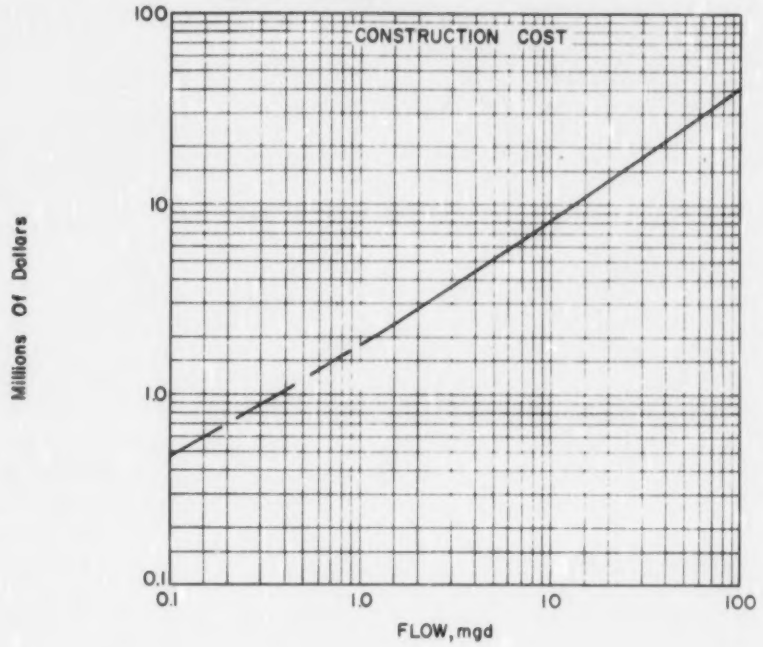
Wastewater Characteristics:	Influent	Effluent
BOD_5, mg/l	210	10
COD, mg/l	400	45
TSS, mg/l	230	10
Total-P, mg/l	11	1
NH_3-N, mg/l	20	2
NO_3-N, mg/l	0	18
UOD, mg/l	406	24

Sludge Audit:

Point No.	Sludge Quantity lbs/mg	Concentration %
1	1,800	3
2	600	0.8
3	2,430	2.5
4	2,430	4
5	1,380	2.5
6	1,380	20

Notes:
1. Dashed line on construction cost curve indicates size range of marginal applicability from a process and/or economic basis.
2. See individual treatment process curves for design basis of specific unit processes. (Adjustment factors should be used where applicable.)
3. Aerobic digestion at plant sizes less than 3 mgd; two-stage anaerobic digestion at plant sizes greater than 3 mgd.

FIGURE H-10 TREATMENT SYSTEM 9-
ACTIVATED SLUDGE/NITRIFICATION - FILTRATION
(WITH ALUM)



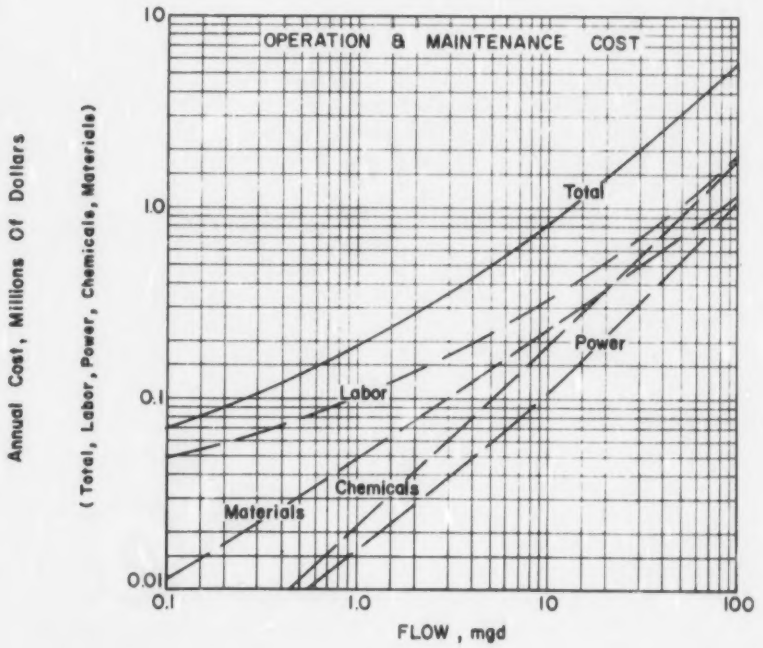
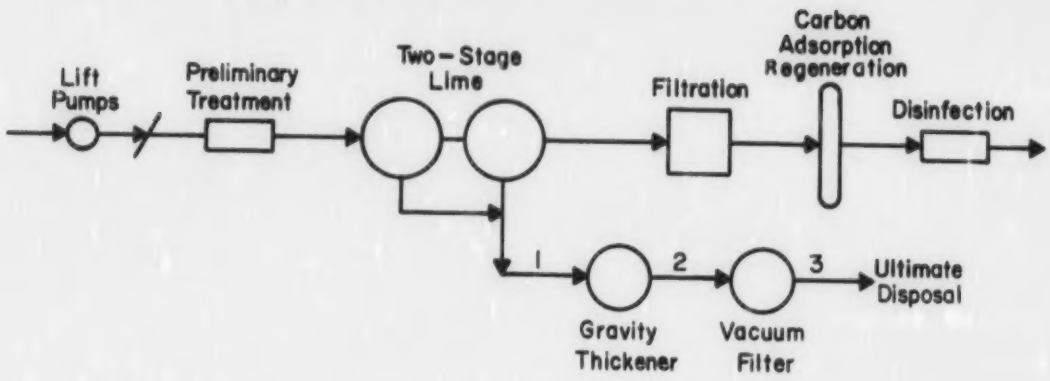


FIGURE H-11 TREATMENT SYSTEM 10-
PHYSICAL/CHEMICAL



Processes Included: Lift Pumps, Preliminary Treatment, Two-Stage Lime, Gravity Filtration, Interstage Pumping, Carbon Adsorption, Chlorination, Gravity Thickener, Vacuum Filters, Miscellaneous Structures, Support Personnel.

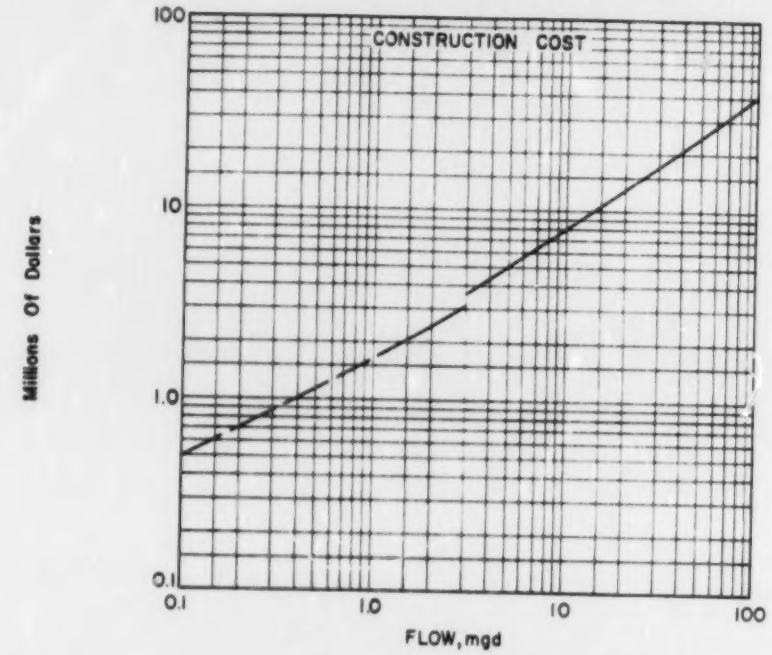
Wastewater Characteristics:	Influent	Effluent
BOD_5, mg/l	210	5
COD, mg/l	400	25
TSS, mg/l	230	5
Total-P, mg/l	11	1
NH_3-N, mg/l	20	20
NO_3-N, mg/l	0	0
UOD, mg/l	406	99

Sludge Audit:

Point No.	Sludge Quantity lbs/mg	Concentration %
1	7,500	5
2	7,500	10
3	7,500	30

Notes:
1. Dashed line on construction cost curve indicates size range of marginal applicability from a process and/or economic basis.
2. See individual treatment process curves for design basis of specific unit processes. (Adjustment factors should be used where applicable.)
3. Lime dosage at 400 mg/l as CaO.
4. Carbon adsorption without regeneration at plant sizes less than 3 mgd; carbon adsorption with regeneration at plant size greater than 3 mgd.

FIGURE H-11 TREATMENT SYSTEM 10-
PHYSICAL/CHEMICAL



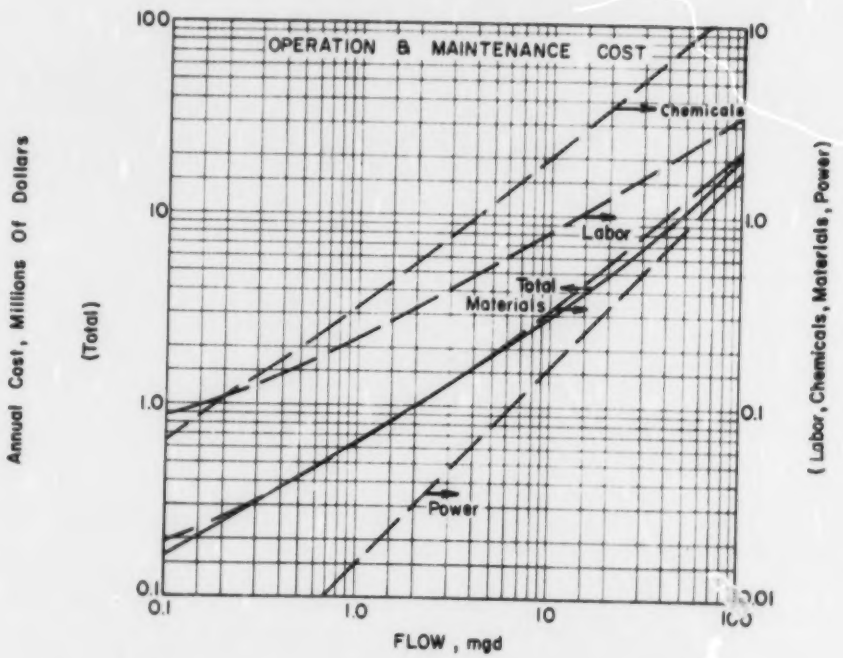
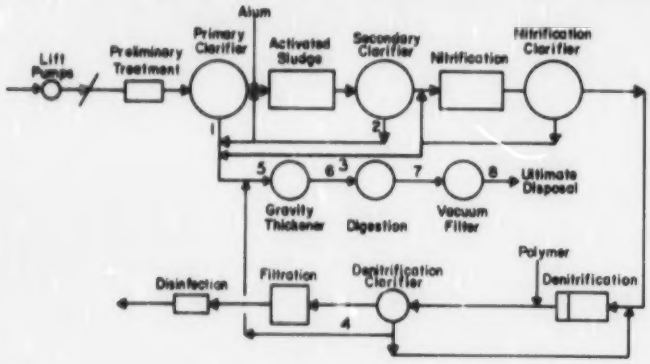


FIGURE H-12 TREATMENT SYSTEM 11-ACTIVATED SLUDGE/ NITRIFICATION/DENITRIFICATION/WITH ALUM (THREE STAGES)



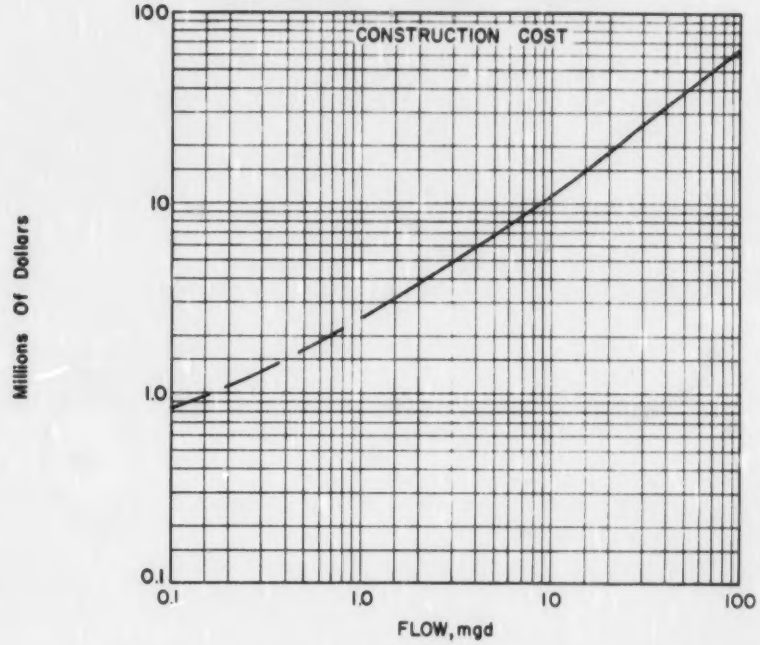
Processes Included: Lift Pumps, Preliminary Treatment, Primary Clarifiers, Alum Addition, Activated Sludge, Secondary Clarifiers, Nitrification, Nitrification Clarifier, Denitrification, Polymer Addition, Denitrification Clarifier, Filtration, Chlorination, Gravity Thickener, Sludge Digestion, Vacuum Filtration, Miscellaneous Structures, Support Personnel.

Wastewater Characteristics:	Influent	Effluent
BOD_5, mg/l	210	5
COD, mg/l	400	30
TSS, mg/l	230	5
Total-P, mg/l	11	0.5
NH_3-N, mg/l	20	1
NO_3-N, mg/l	0	1
UOD, mg/l	406	12

Sludge Audit: Point No.	Sludge Quantity lbs/mg	Concentration %
1	1,080	4
2	1,050	0.8
3	100	0.8
4	280	0.8
5	2,510	2.8
6	2,510	4
7	1,420	3
8	1,420	20

Notes:
1. Dashed line on construction cost curve indicates size range of marginal applicability from a process and/or economic basis.
2. See individual treatment process curves for design basis of specific unit processes. (Adjustment factors should be used where applicable.)
3. Aerobic digestion at plant sizes less than 3 mgd; two-stage anaerobic digestion at plant sizes greater than 3 mgd.

FIGURE H-12 TREATMENT SYSTEM 11-
ACTIVATED SLUDGE / NITRIFICATION / DENITRIFICATION
WITH ALUM (THREE STAGES)



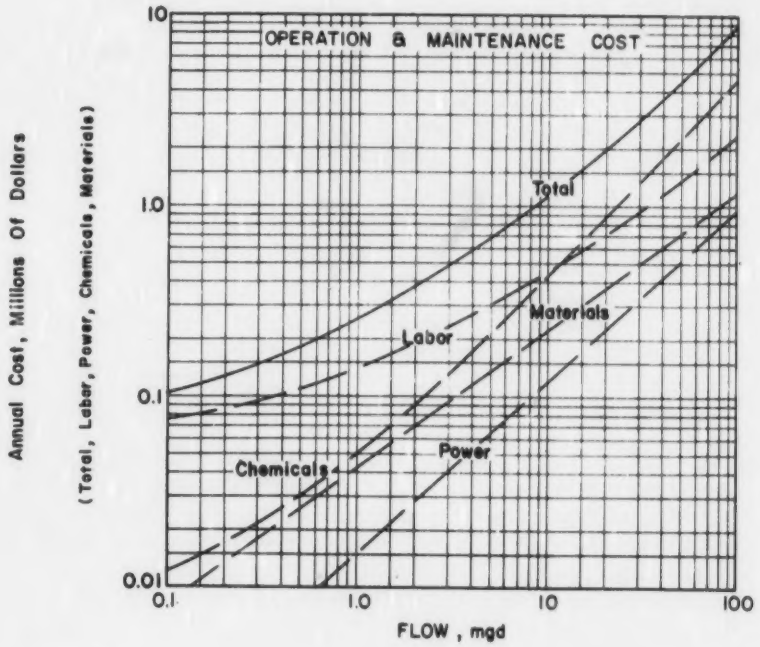
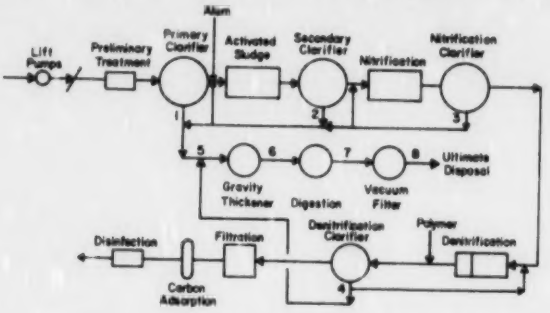


FIGURE H-13 TREATMENT SYSTEM 12-ACTIVATED SLUDGE/NITRIFICATION/ DENITRIFICATION/ACTIVATED CARBON (WITH ALUM)



Processes Included: Lift Pumps, Preliminary Treatment, Primary Clarifiers, Alum Addition, Activated Sludge, Secondary Clarifier, Nitrification, Nitrification Clarifier, Denitrification, Polymer Addition, Denitrification Clarifier, Filtration, Interstage Pumping, Carbon Adsorption, Chlorination, Gravity Thickener, Digestion, Vacuum Filter, Miscellaneous Structures, Support Personnel.

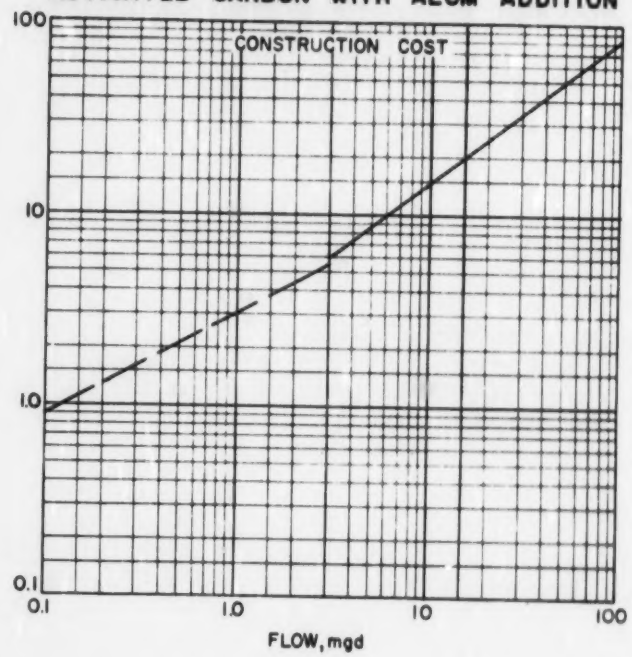
Wastewater Characteristics:	Influent	Effluent
BOD_5, mg/l	210	3
COD, mg/l	400	10
TSS, mg/l	230	5
Total-P, mg/l	11	0.5
NH_3-N, mg/l	20	1
NO_3-N, mg/l	0	1
UOD, mg/l	406	12

Sludge Audit:

Point No.	Sludge Quantity lbs/mg	Concentration %
1	1,080	4
2	1,050	1
3	100	0.8
4	280	0.8
5	2,510	2.8
6	2,510	4
7	1,420	3
8	1,420	20

Notes:
1. Dashed line on construction cost curve indicates size range of marginal applicability from a process and/or economic basis.
2. See individual treatment process curves for design basis of specific unit processes. (Adjustment factors should be used where applicable.)
3. Carbon adsorption without regeneration at plant sizes less than 3 mgd; carbon adsorption with regeneration at plant sizes greater than 3 mgd.

FIGURE H-13 TREATMENT SYSTEM 12-
ACTIVATED SLUDGE/NITRIFICATION/DENITRIFICATION/
ACTIVATED CARBON WITH ALUM ADDITION



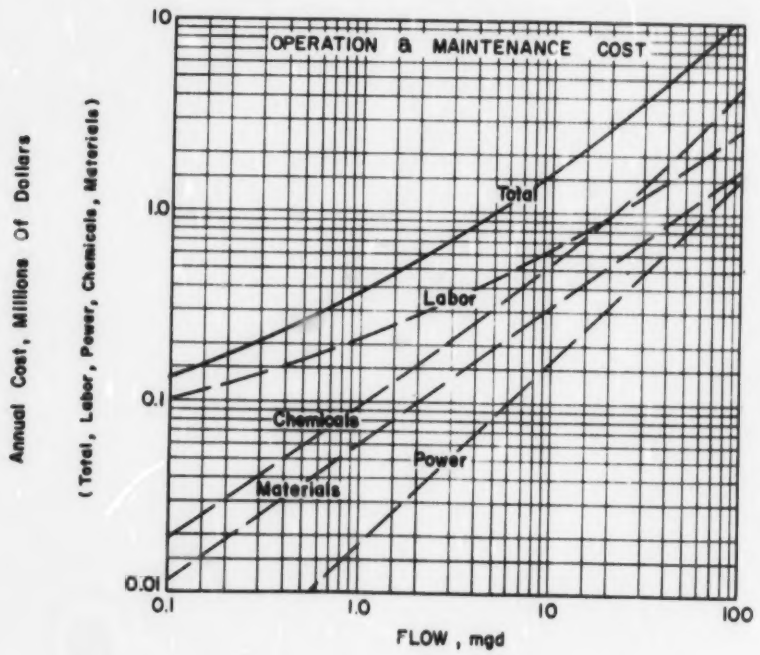


FIGURE H-14

TREATMENT SYSTEM 13
SMALL FLOW TREATMENT SYSTEMS

Service Life: 30 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include:

   a. Comminutor
   b. Aeration basin
   c. Clarifier
   d. Chlorine contact chamber
   e. Aerobic digester
   f. Chlorine feed facility
   g. Building
   h. Fencing

2. Extended aeration (E.A.) between 0.01 and 0.1 mgd.
   Detention time: 24 hours.

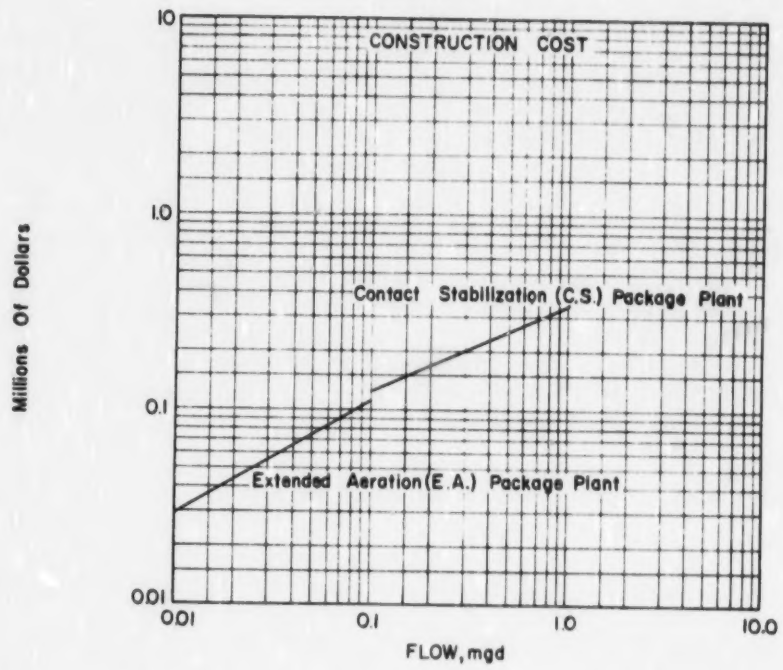
3. Contact stabilization (C.S.) between 0.1 and 1.0 mgd.
   Detention time: 3 hours contact; 6 hours stabilization.

4. Process Performance:

Wastewater Characteristics:	Influent	Effluent	
		C.S.	E.A.
BOD_5, mg/l	210	25	20
COD, mg/l	400	50	45
TSS, mg/l	230	25	20
Total-P, mg/l	11	7	7
NH_3-N, mg/l	20	17	2

References: 9, 43, 47

FIGURE H-14 TREATMENT SYSTEM 13-
SMALL FLOW TREATMENT SYSTEMS



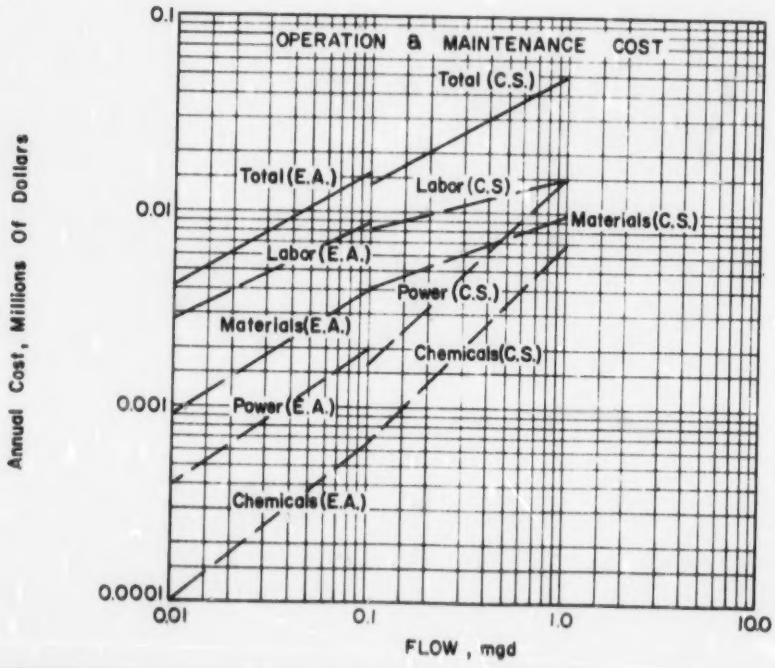


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FIGURE H-15

TREATMENT SYSTEM 14
OXIDATION DITCH (DESIGNED FOR NITRIFICATION)

Service Life: 30 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include:

   a. Comminutor
   b. Aeration basin
   c. Clarifier
   d. Chlorine contact chamber
   e. Chlorine feed facility
   f. Building
   g. Fencing

2. Detention time: 24 hours

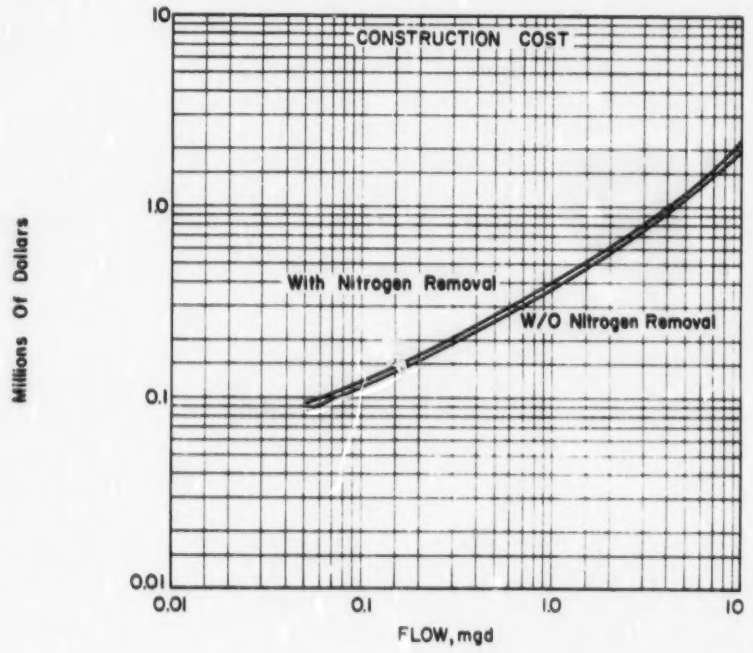
3. Process Performance:

Wastewater Characteristics:	Influent	Effluent	
		w/N Removal	w/o N Removal
BOD_5, mg/l	210	15	15
COD, mg/l	400	40	40
TSS, mg/l	230	15	15
Total-P, mg/l	11	6	6
NH_3-N, mg/l	20	1	1
NO_3-N, mg/l	0	2	18

Note: O & M costs are w/o nitrogen removal. Add 5 - 10% annual O & M costs to those shown w/ nitrogen removal.

Reference: 47

FIGURE H-15 TREATMENT SYSTEM 14-
OXIDATION DITCH (DESIGNED FOR NITRIFICATION)



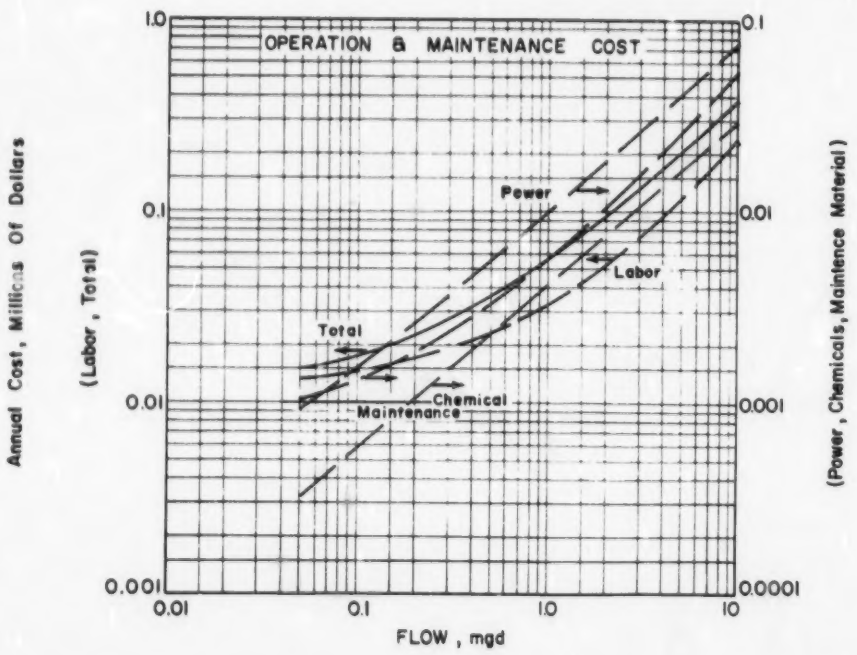


FIGURE H-16

TREATMENT SYSTEM 15
LAND APPLICATION OF WASTEWATER (NON-UNDERDRAINED)

Service Life: 30 years (equipment only)
(Land assumed to have infinite service life)

Relative Reliability: Level B

Design Basis:

1. Costs are for spray irrigation of wastewater.

2. Construction costs include:

   a. Storage - 60 days' retention (based on average flow of wastewater), earthen construction, asphalt-lined with riprap.

   b. Land - to include storage area; land required for 2"/wk application rate; 200 ft buffer zone.

   c. Field preparation - to include brush and tree removal and site leveling at 500 cu yd/acre.

   d. Distribution piping.

   e. Distribution pumping.

   f. Service roads and fencing.

   g. Monitoring wells.

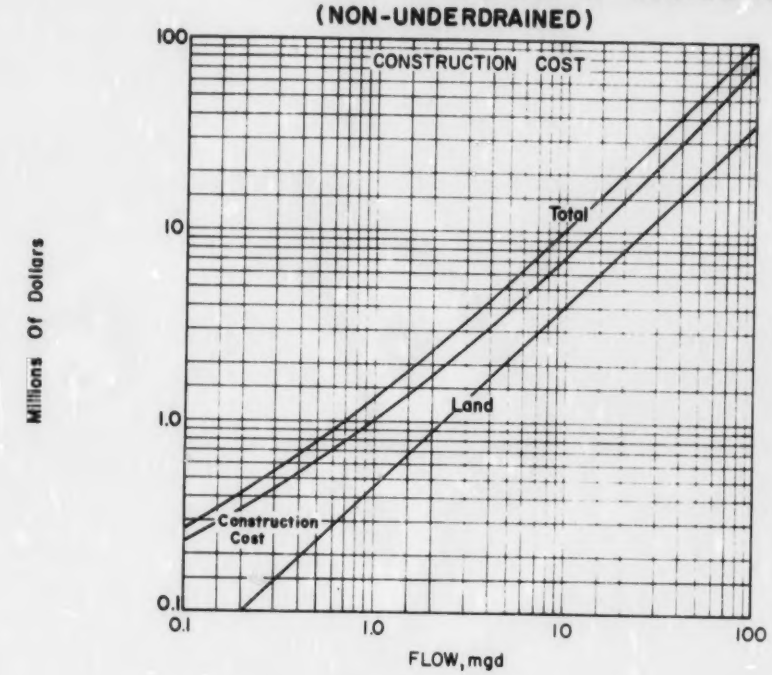
Adjustment Factor:

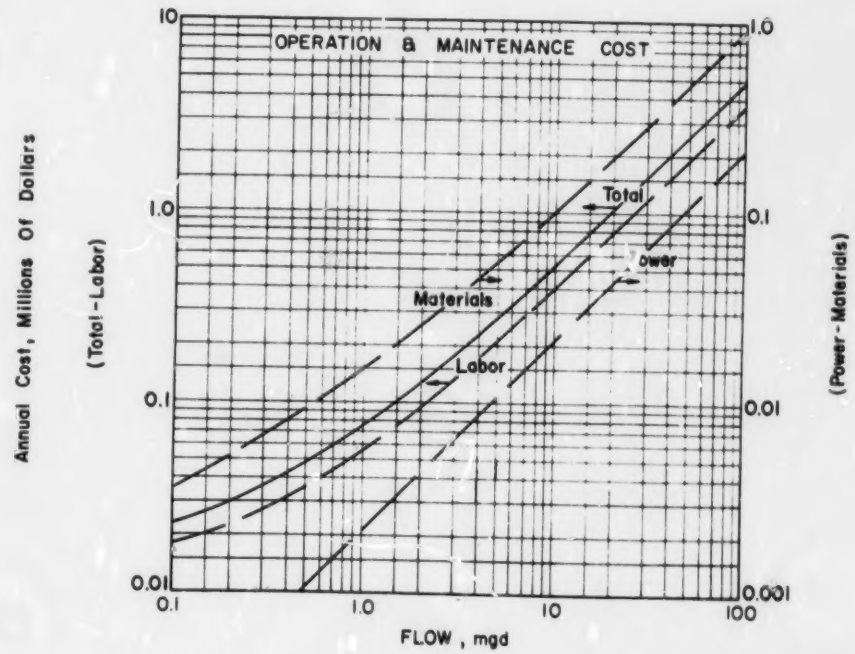
To adjust for application rate other than above, enter curve at effective flow (Q_E):

$$Q_E = Q_{DESIGN} \times \frac{2" \text{ Week}}{\text{New Application Rate}}$$

Reference: 27

FIGURE H-16 TREATMENT SYSTEM 15-
LAND APPLICATION OF WASTEWATER
(NON-UNDERDRAINED)





H.7 Wet-Weather Treatment Processes
Cost Curves:

Figures H-17 through H-27

FIGURE H-17

CONCRETE STORMWATER STORAGE RESERVOIR

Service Life: 50 years

Relative Reliability: Level B

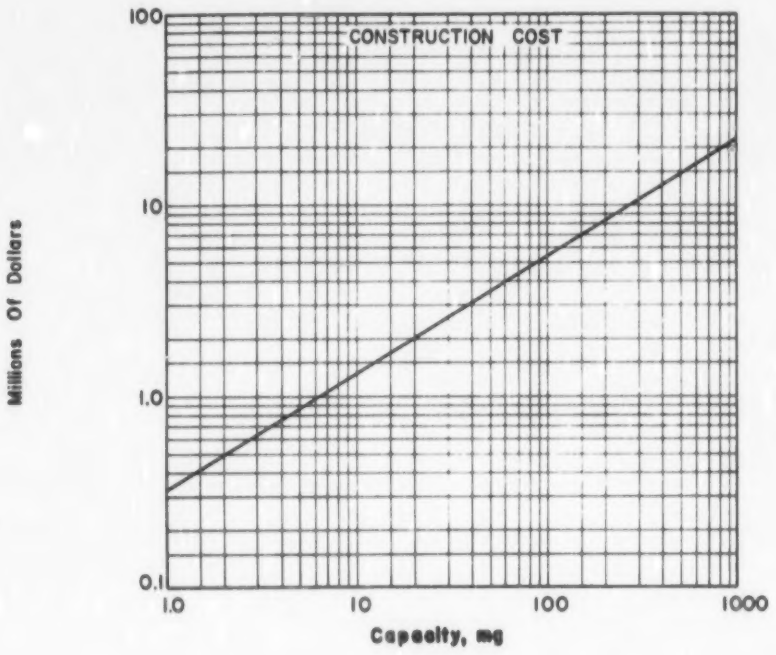
Design Basis:

1. Construction costs based on actual projects and on comparison with sludge aeration basins exclusive of aeration equipment ranging from 400,000 to 5,000,000 gallons.

2. Operation and maintenance costs include automatic washdown of basins after storms.

Reference: 36

FIGURE H-17[1] CONCRETE STORMWATER STORAGE RESERVOIR (WITHOUT COVER)



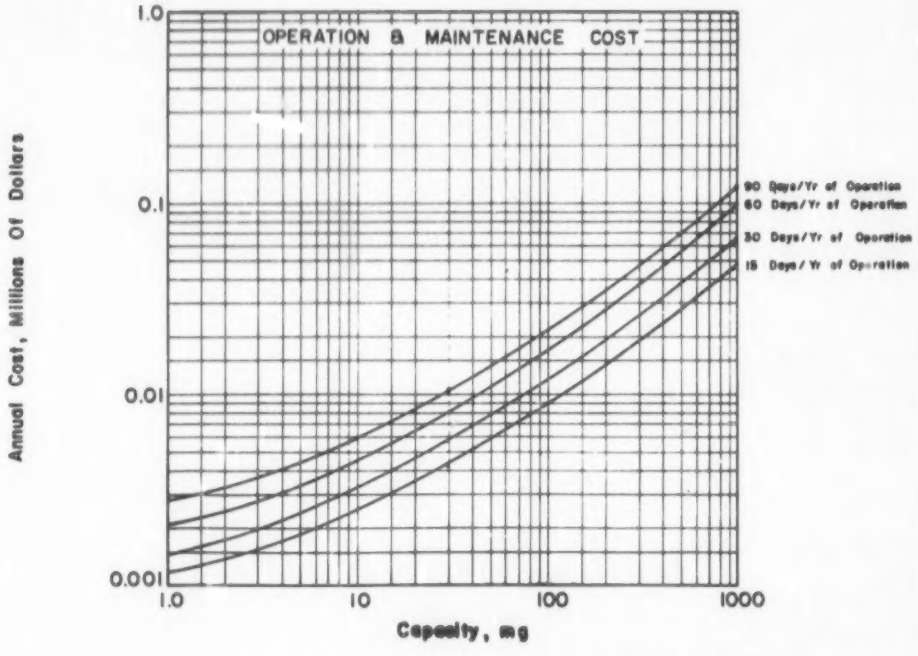


FIGURE H-17

CONCRETE STORMWATER STORAGE RESERVOIR

Service Life: 50 years

Relative Reliability: Level B

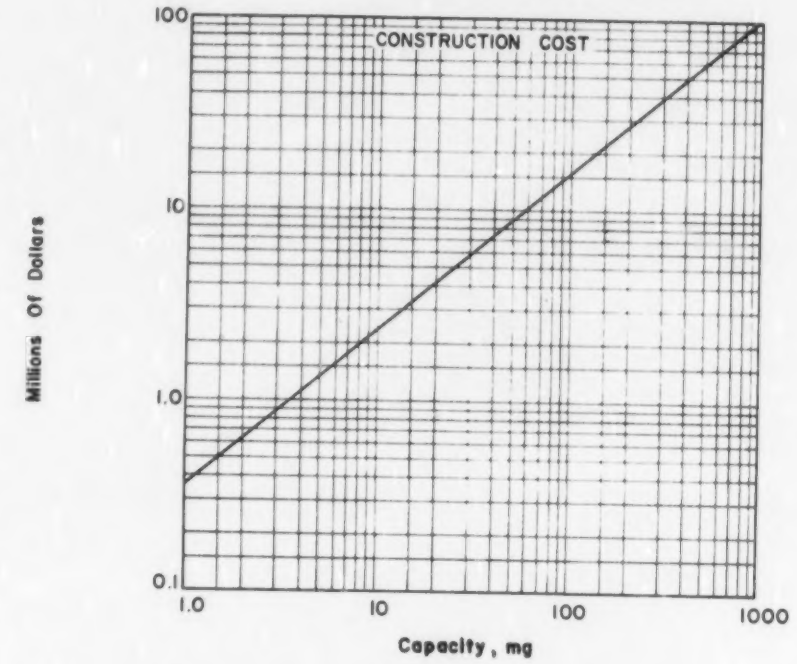
Design Basis:

1. Construction costs based on actual projects and on comparison with sludge aeration basins exclusive of aeration equipment ranging from 400,000 to 5,000,000 gallons.

2. Operation and maintenance costs include automatic washdown of basins after storms.

Reference: 36

FIGURE H-17[2] CONCRETE STORMWATER STORAGE RESERVOIR (WITH COVER)



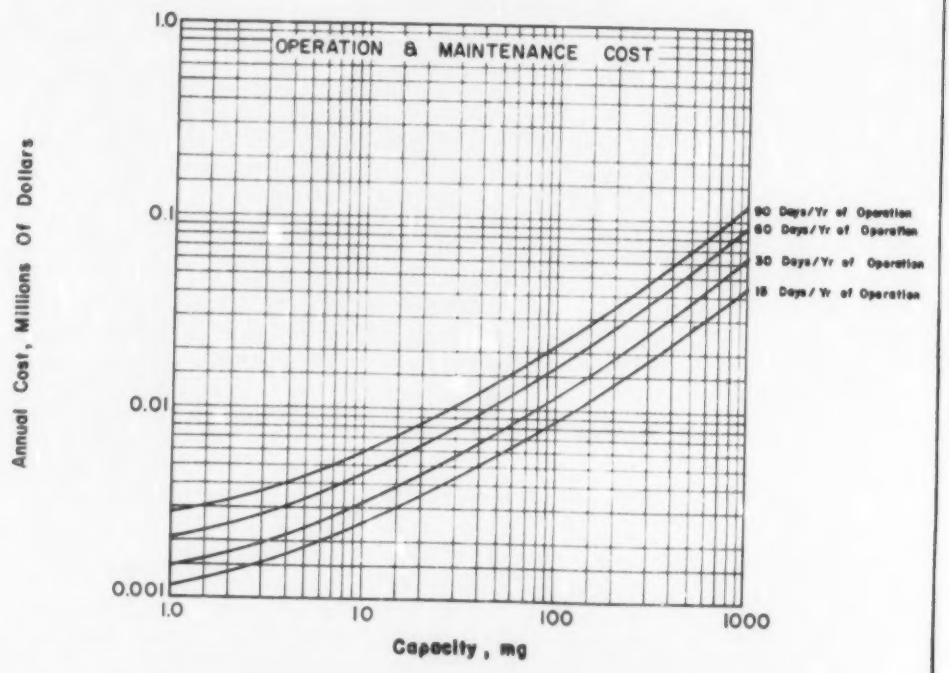


FIGURE H-18

EARTHEN STORAGE BASIN

Service Life: 50 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include liner, paving and fencing, on-site soil supply, and no groundwater problems or rock excavation.

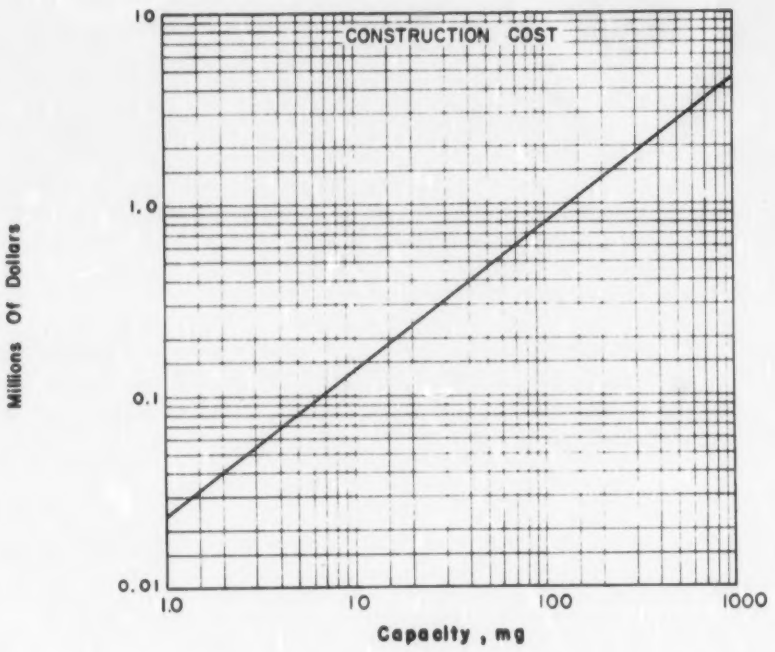
2. Interior slope is 2.5 to 1.
   Exterior slope is 3 to 1.
   Compaction loss = 20%.
   Levee top width = 16 feet.
   Reservoir is 18 feet deep.
   Length/width ratio is 2.

3. Manual cleanout twice a year based on 0.004 manhours/sq ft of basin water surface area.

4. No electrical costs.

Reference: 36

FIGURE H-18 EARTHEN STORAGE BASIN



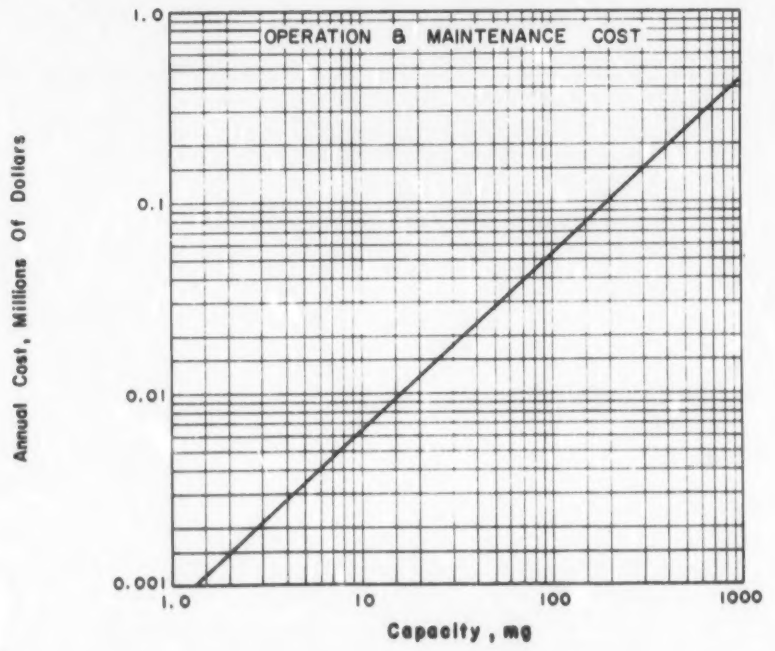


FIGURE H-19

STATIONARY SCREEN

Service Life: 15 years

Relative Reliability: Level B

Design Basis:

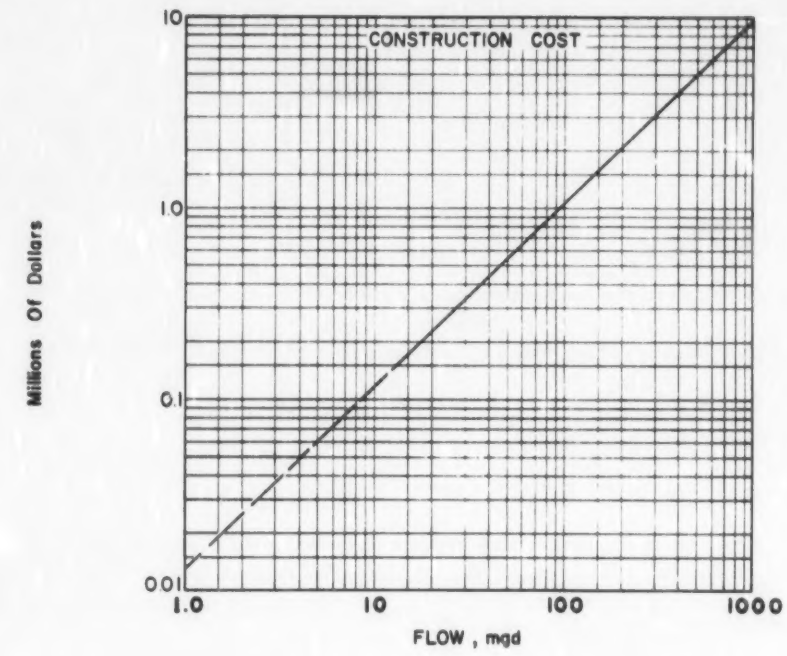
1. Construction costs include collection flumes for sludge and screened effluent, and housing for screens.
2. Screens are wedgewire (stainless steel).
3. Costs based on screens rated at 4 mgd each. Total capacities range from 12 mgd (3 screens) to 192 mgd (48 screens).
4. Costs are related to hydraulic capacity.
5. Screen assembly requires 4 to 8 feet of head loss.
6. Costs include influent headers and metal weirs to distribute flow to each unit.
7. Labor costs include 24 hours/year for routine checks. Also for each overflow event: 1 hour startup/shutdown time, 1 hour wash time, 1 hour travel time, and 2 hours twice a day for operation.

Process Performance: (Swirl Concentrator Followed By Stationary Screen)

	Typical Pollutant Removals, %
BOD_5	0 - 25
TSS	0 - 25

References: 36, 51

FIGURE H-19 STATIONARY SCREEN



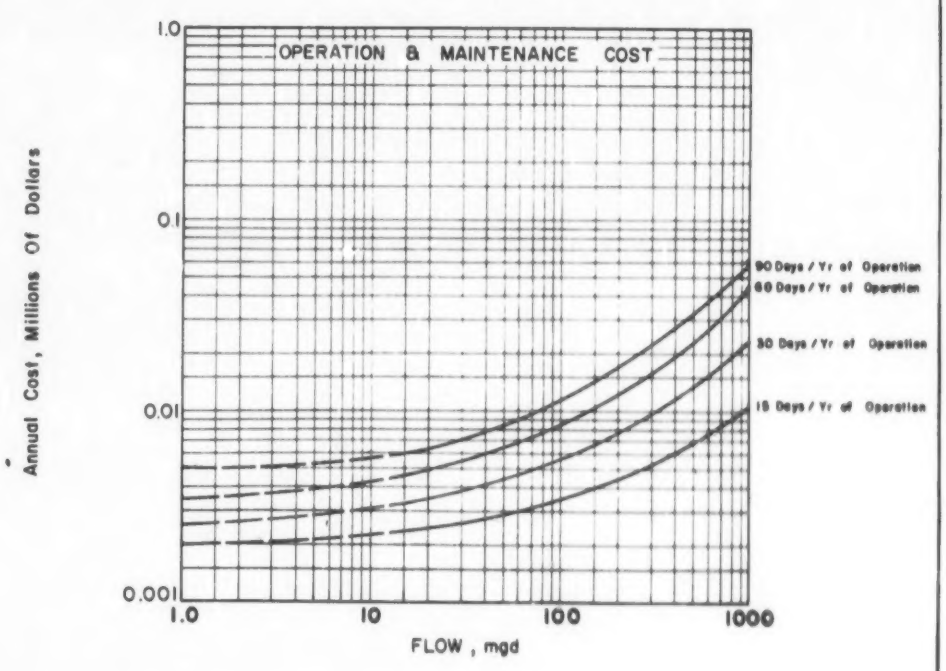


FIGURE H-20

HORIZONTAL-SHAFT ROTARY SCREEN

Service Life: 15 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include housing for gallery and screen chambers.
2. Loading rate = 14 sq ft screen/mgd.
3. Screen submergence varies from 74% to 83%.
4. Screen opening (Microns): Pretreatment 150-420; complete treatment 23-35.
5. Screen material is stainless steel.
6. Drum speed = 0-7 rpm.
7. Labor costs include 48 hours/yr for routine checks and 3 hr/yr/screen for maintenance. Also, for each overflow event: 1 hour setup/shutdown time, 1 hour travel time, 3 hours/screen for cleanup time, and 4 hours/day for operation.

Process Performance:

	Typical Pollutant Removals, %
BOD_5	40 - 60
SS	50 - 70

References: 36, 42, 51

FIGURE H-20 HORIZONTAL-SHAFT ROTARY SCREEN

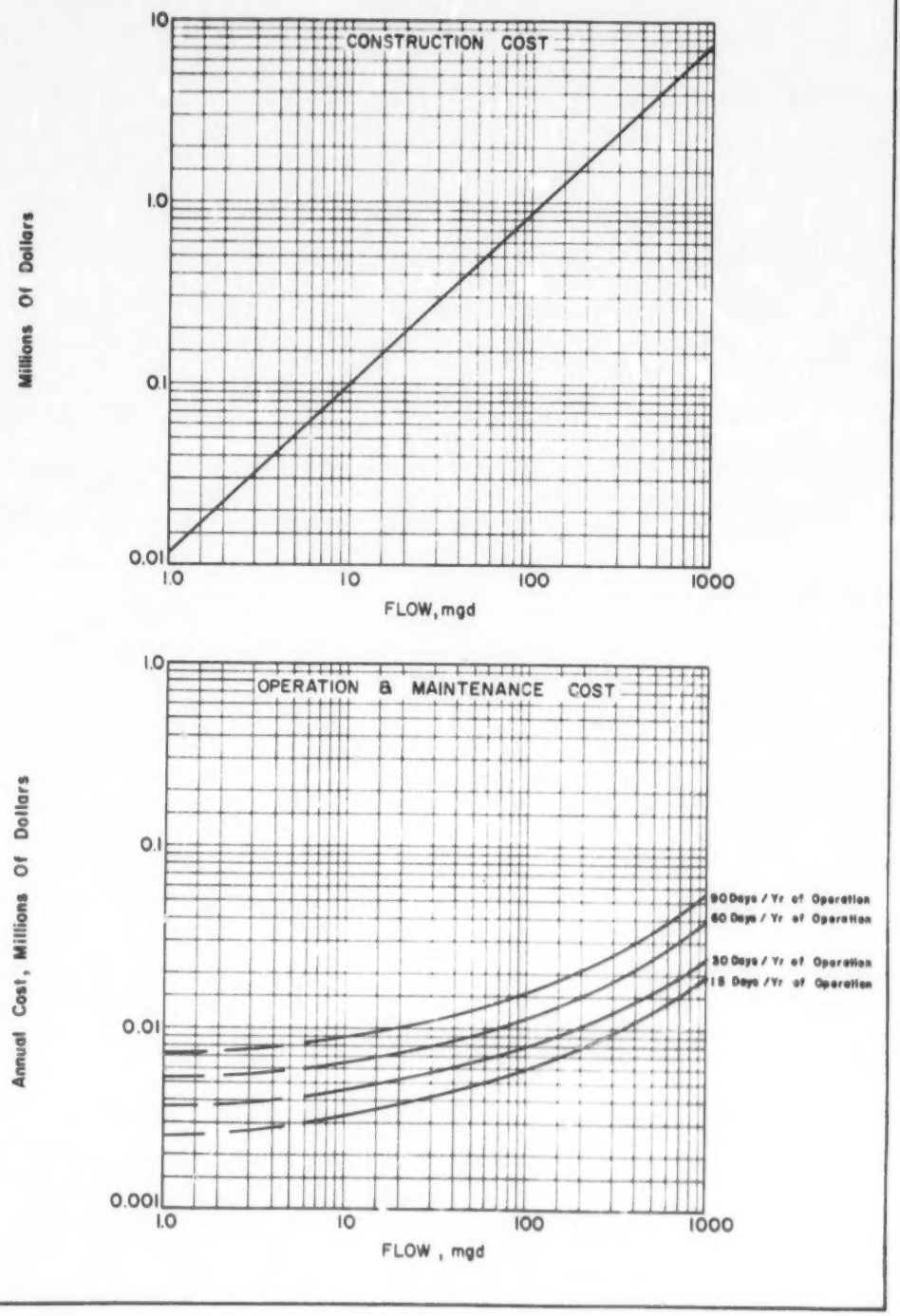


FIGURE H-21

VERTICAL-SHAFT ROTARY SCREEN

Service Life: 15 years

Relative Reliability: Level B

Design Basis:

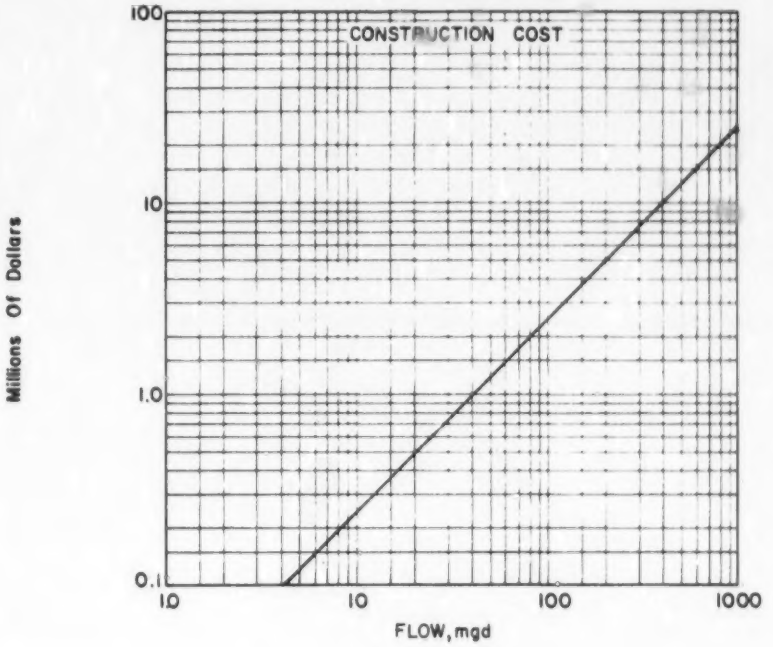
1. Construction costs include housing for equipment.
2. Cost data are developed for multiple use of 3-mgd, 60 inch screens.
3. Screen openings range from 74 to 230 microns.
4. Screen material is stainless steel.
5. Drum speed is 30-65 rpm.
6. Labor costs include 48 hours/yr for routine checks and 6 hours/yr/screen for maintenance. Also, for each overflow event: 1 hour/screen shutdown time for plant cleanup and 4 hours/day for operation.

Process Performance:

	Typical Pollutant Removals, %
BOD_5	( )
TSS	( )

References: 36, 42, 51

FIGURE H-21 VERTICAL-SHAFT ROTARY SCREEN



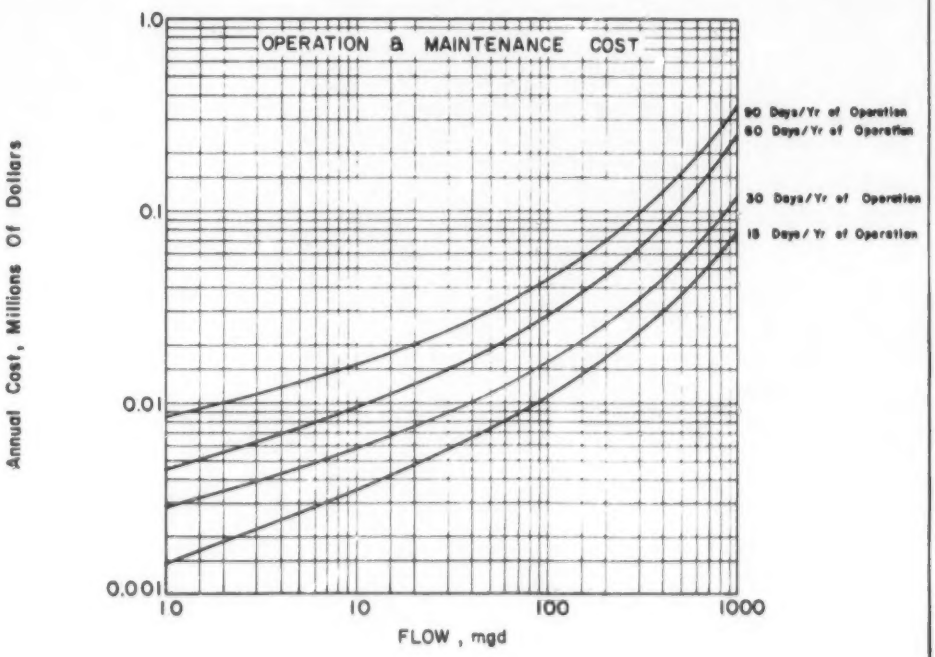


FIGURE H-22

CHEMICAL COAGULATION
(FERRIC CHLORIDE AND POLYMER)

Service Life: 35 years

Relative Reliability: Level B

Design Basis:

1. Velocity gradient, G = 20 to 70 sec^{-1} for flocculation, G = 300 sec^{-1} for rapid mix.

2. Detention time is 20 minutes for flocculation, 1 minute for rapid mix.

3. Reinforced concrete basins.

4. Turbine type mixers.

5. For ferric chloride:

   a. Pump costs based on two 25 gallon/hour hydraulic pumps to four 50 gallon/min pumps.

   b. Storage tanks range from two 3,000 gallon fiberglass reinforced plastic (FRP) tanks to ten 50,000 gallon underground concrete tanks with rubber linings.

   c. Ferric chloride dosage = 100 mg/l.

   For polymer:

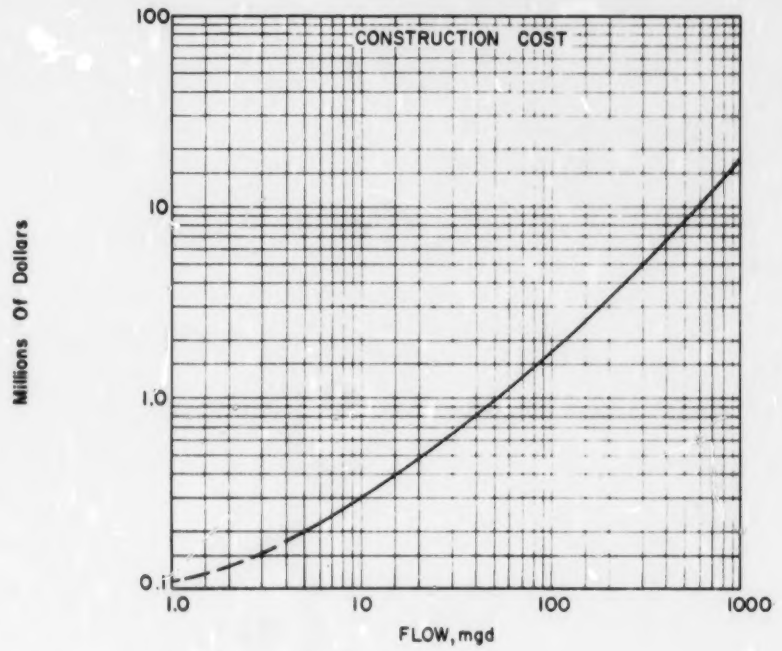
   a. Feed costs range from manual feed to four volumetric dry feeders, four mixing tanks and two holding tanks.

   b. Polymer dosage = 0.5 mg/l.

6. Operation and maintenance costs include 0.004 manhours/sq ft/storm overflow event and 0.7 hp/mgd.

Reference: 36

FIGURE H-22[1] CHEMICAL COAGULATION
(FERRIC CHLORIDE AND POLYMER)



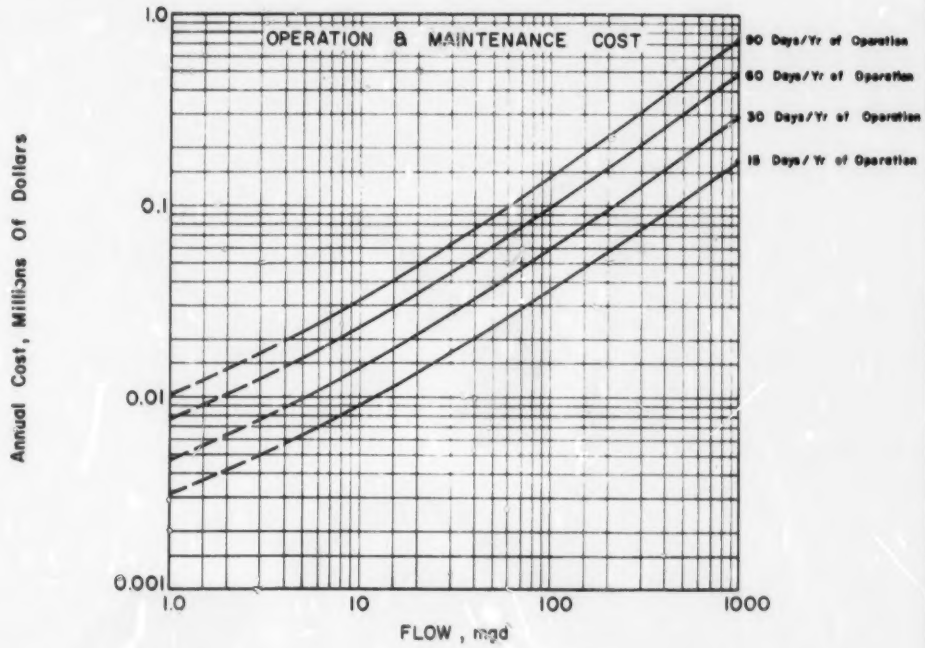


FIGURE H-22

CHEMICAL COAGULATION
(FERRIC CHLORIDE AND POLYMER)

Service Life: 35 years

Relative Reliability: Level B

Design Basis:

1. Velocity gradient, G = 20 to 70 sec^{-1} for flocculation, G = 300 sec^{-1} for rapid mix.

2. Detention time is 20 minutes for flocculation, 1 minute for rapid mix.

3. Reinforced concrete basins.

4. Turbine type mixers.

5. For ferric chloride:

   a. Pump costs based on two 25 gallon/hour hydraulic pumps to four 50 gallon/min pumps.

   b. Storage tanks range from two 3,000 gallon fiberglass reinforced plastic (FRP) tanks to ten 50,000 gallon underground concrete tanks with rubber linings.

   c. Ferric chloride dosage = 100 mg/l.

   For polymer:

   a. Feed costs range from manual feed to four volumetric dry feeders, four mixing tanks and two holding tanks.

   b. Polymer dosage = 0.5 mg/l.

6. Operation and maintenance costs include 0.004 manhours/sq ft/storm overflow event and 0.7 hp/mgd.

Reference: 36

FIGURE H-22[2] CHEMICAL COAGULATION (POLYMER)

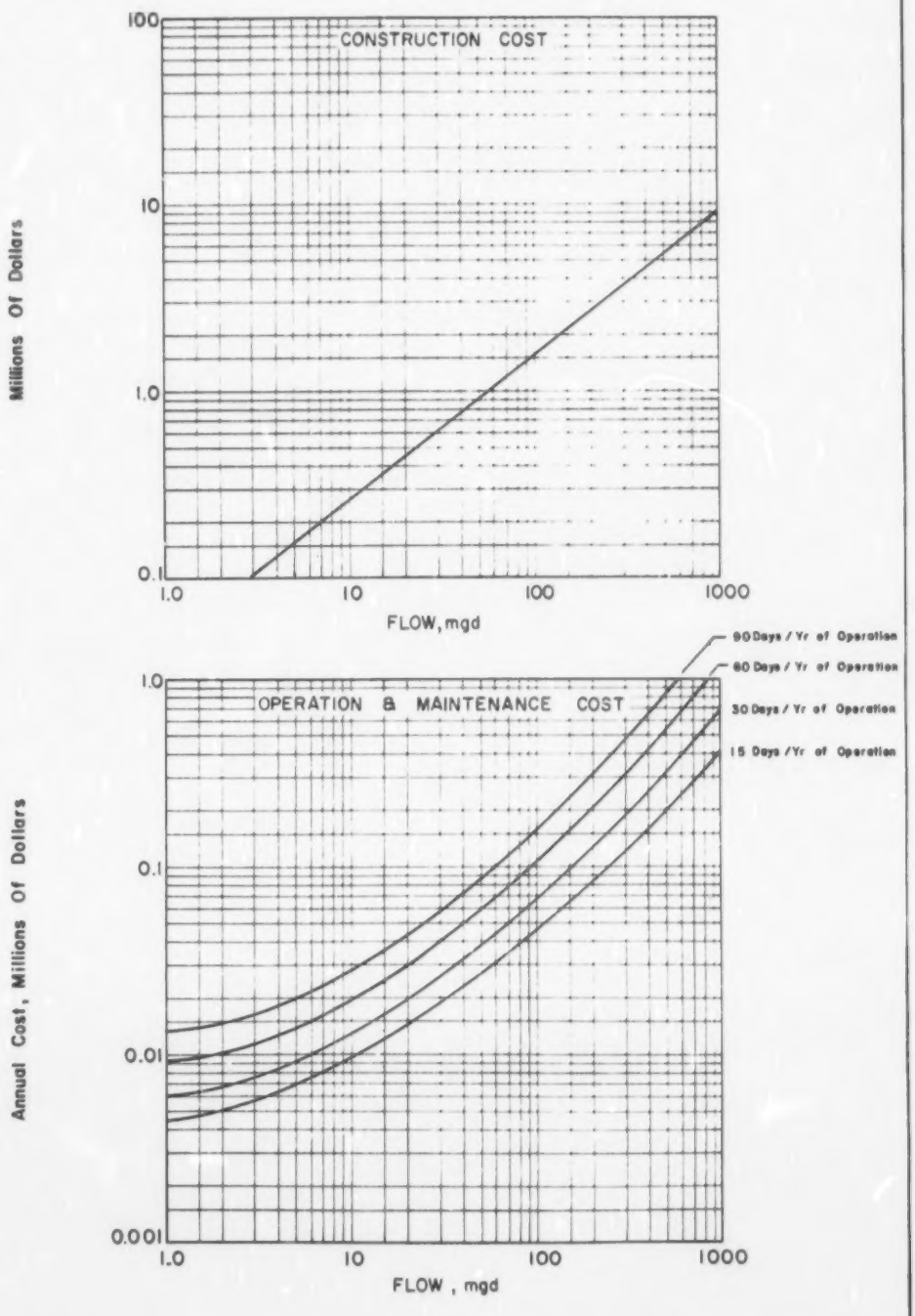


FIGURE H-23

STORMWATER SEDIMENTATION

Service Life: 40 years

Relative Reliability: Level B

Design Basis:

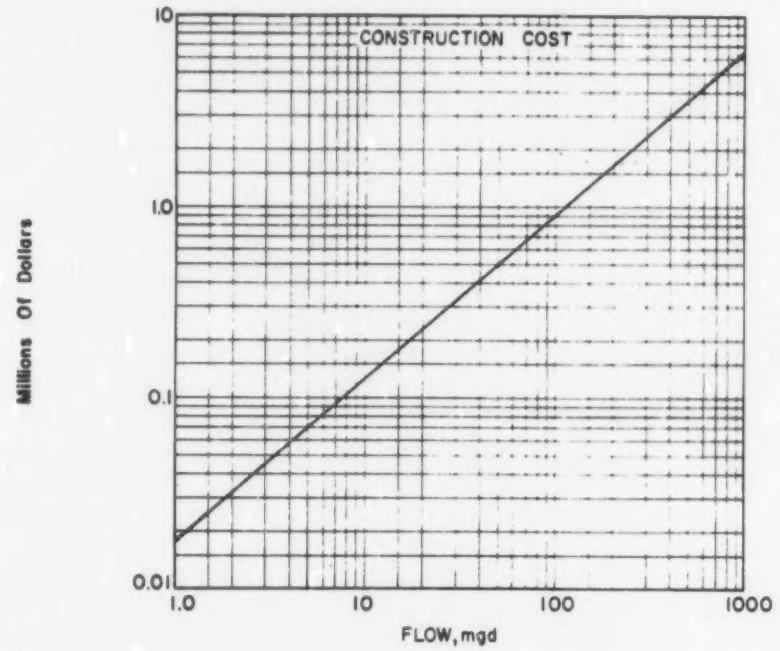
1. Cost is based on recommended design flow of 3,000 gpd/sq ft of surface area.
2. Basins have side water depth of 12 feet and freeboard of 1.5 feet.
3. Costs apply to circular sludge collection equipment in circular basins and large rectangular basins (20,000 sq ft). Costs do not apply to straight-line sludge collection equipment.
4. Costs do not include sludge removal or disposal.
5. Construction cost includes steel troughs and weirs.

Process Performance:

	Typical Pollutant Removals, %
BOD_5	25 - 40
SS	25 - 50

References: 36, 51

FIGURE H-23 STORMWATER SEDIMENTATION



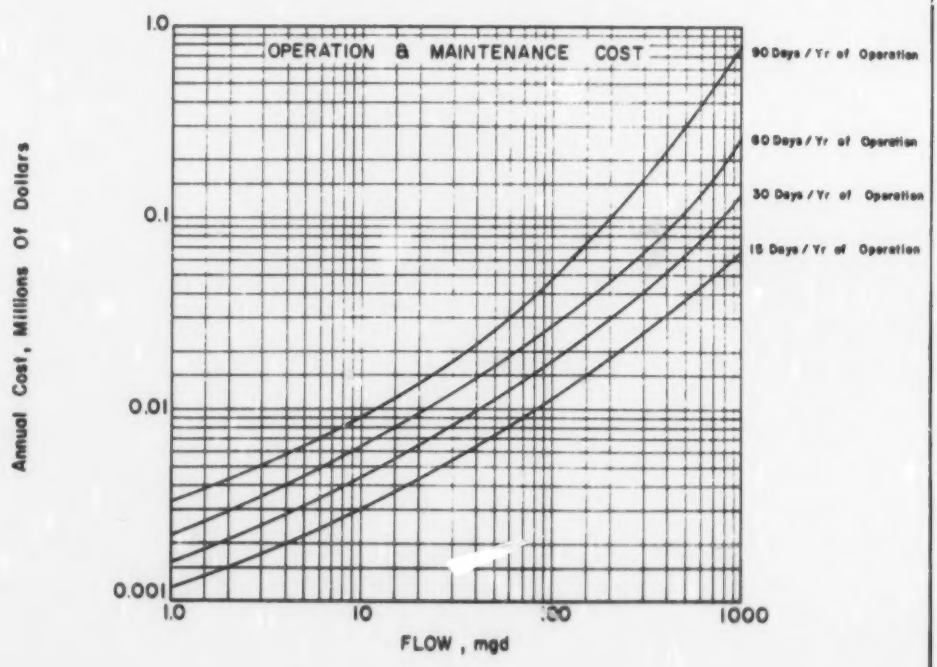


FIGURE H-24

DISSOLVED AIR FLOTATION

Service Life: 40 years

Relative Reliability: Level B

Design Basis:

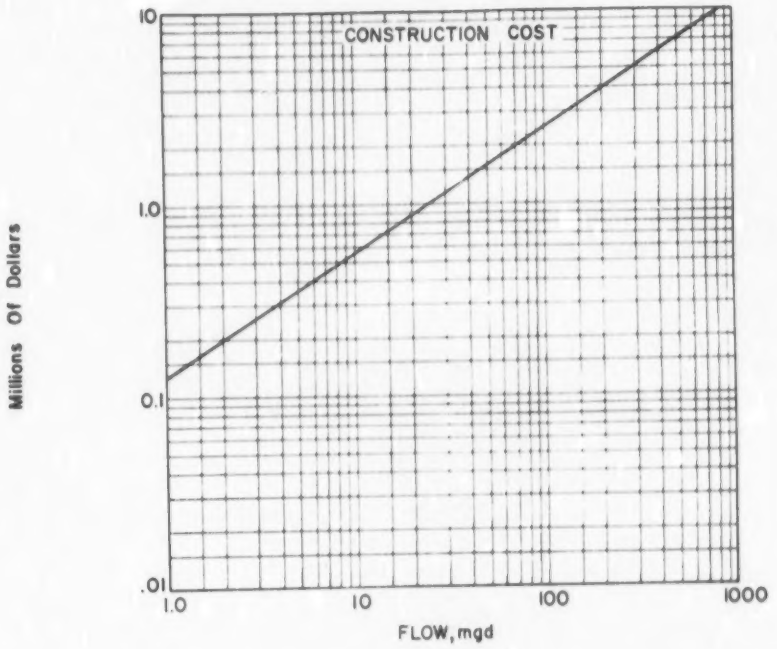
1. Costs are based on an overflow rate of 4,440 gpd/sq ft of surface area.
2. Construction cost includes the basic unit, flow splitting device, and an enclosed piping and equipment gallery for drive equipment, pumps, air tanks and miscellaneous equipment.
3. Largest practical size for an individual unit is 20 ft X 100 ft.
4. Power cost is based on 0.10 kw hr/sq ft.
5. No chemical costs are included.
6. Operations and maintenance costs include 48 hours/yr for routine checks, 0.009 hours/sq ft for maintenance. Also, for each overflow event: 1 hour travel time, 1 hour setup/shutdown time, 0.004 hours/sq ft for washdown, and 4 hours/day operation.

Process Performance: (With Chemicals)

	Typical Pollutant Removals, %
BOD_5	40 - 60
SS	50 - 70

References: 36, 37, 51

FIGURE H-24 DISSOLVED AIR FLOTATION



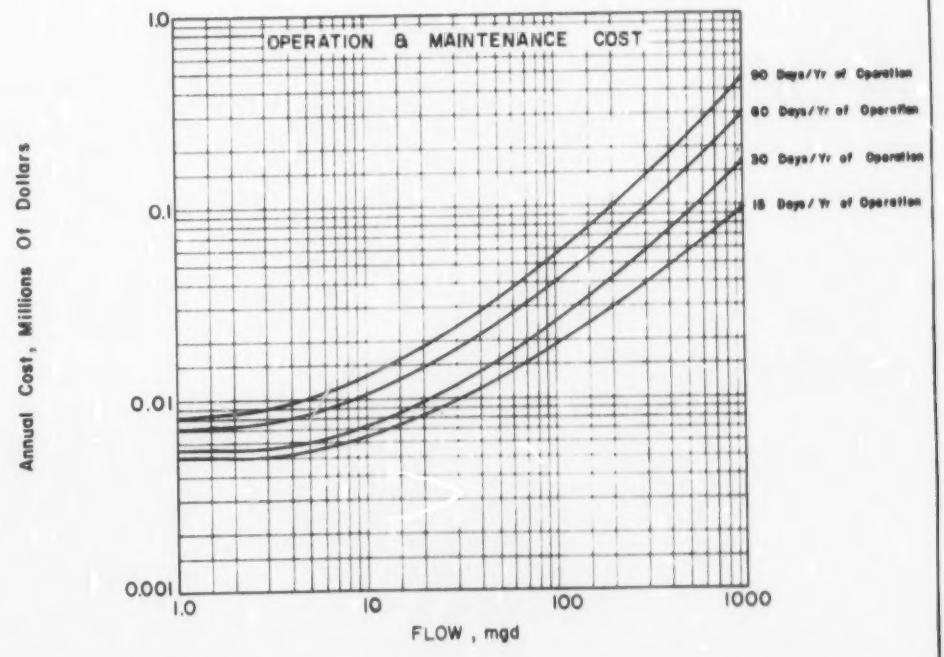


FIGURE H-25

SWIRL REGULATOR/CONCENTRATOR

Service Life: 50 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include basic chamber. Costs do not include buildings, pumping stations, flow measurement, or basin dewatering facilities.

2. Chamber diameters range from 12 ft to 48 ft.

3. Labor costs include 52 hours/yr for routine inspections, plus process cleanup after storm overflow events.

4. Process cleanup based on following schedule/storm event:

Flow mgd	Manhours/Storm
5	12
15	14.4
30	15.9
50	20.4
80	22.9
150	25.4
250	27.9

Process Performance: (Swirl Concentrator Followed By Stationary Screen)

	Typical Pollutant Removals, %
BOD_5	0 - 25
SS	0 - 25

References: 36, 37, 51

FIGURE H-25 SWIRL REGULATOR/CONCENTRATOR

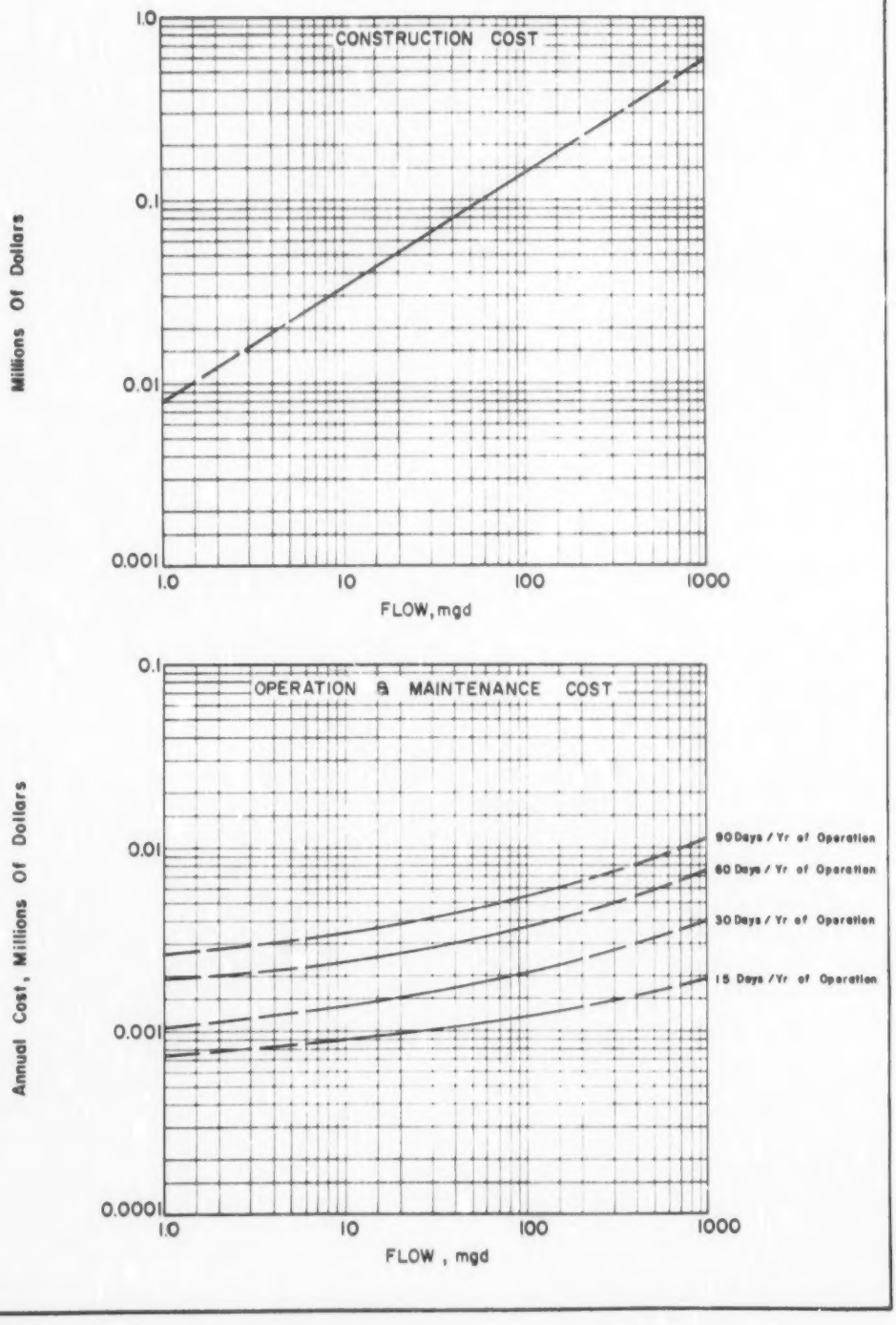


FIGURE H-26

HIGH-INTENSITY MIXING/CHLORINE CONTACT BASIN

Service Life: 50 years

Design Basis:

1. Costs are based on 2-minute detention time and on velocity gradient (G) of 300 sec^{-1}.
2. Construction costs include concrete mixing basin and stainless steel mixers.
3. Miscellaneous costs such as chlorine storage area, hoist, and evaporator are not included.
4. Labor costs include 8 hours/yr/unit for routine maintenance. Also, for each overflow event: 8 hours for cleaning and 1 hour/day operation.
5. Power requirement is 1.25 hp/mgd.

References: 36, 37

FIGURE H-26 HIGH-INTENSITY MIXING / CHLORINE CONTACT BASIN

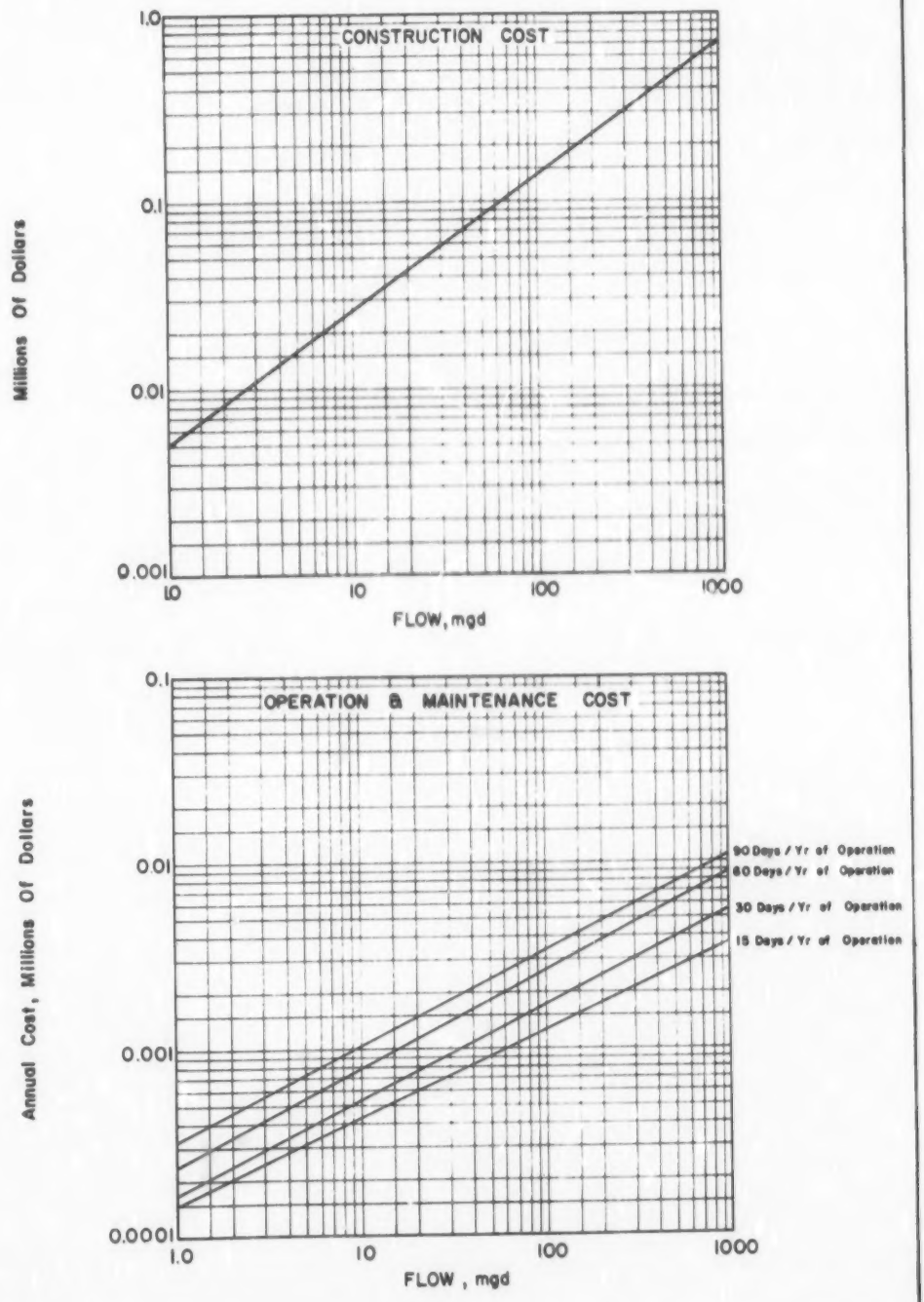


FIGURE H-27

HIGH-RATE FILTRATION (GRAVITY)

Service Life: 40 years

Relative Reliability: Level B

Design Basis:

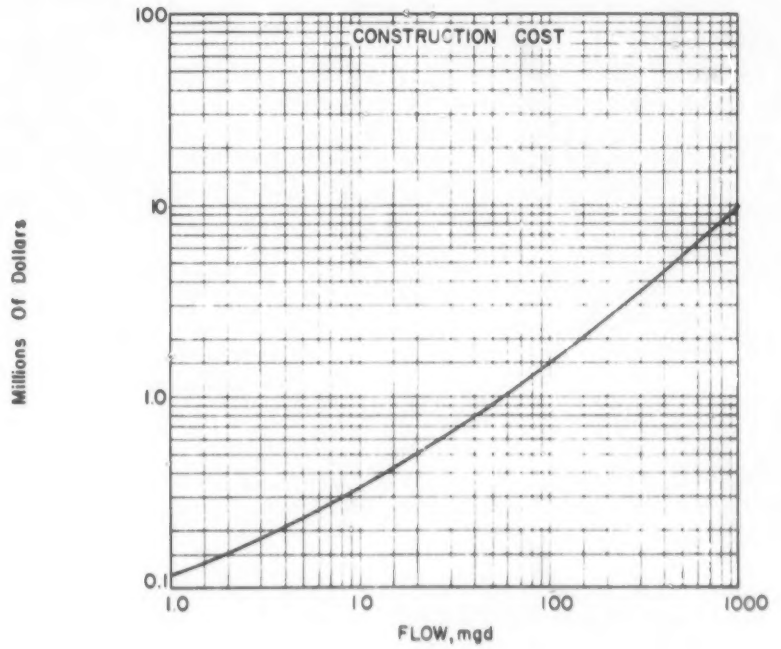
1. Construction cost includes the filters, dual non-proprietary filter media, and housing for filters and filter galleries.
2. Application rate is 16 gpm/sq ft.
3. Maximum headloss is 12 feet.
4. Pumping costs other than backwash and surface wash are not included.
5. Labor costs include 48 hours/yr for routine checks and 12 hours/yr/filter for maintenance. Also, for each overflow event: 1 hour startup and shutdown, 1 hour/filter cleanup, and 4 hours/day for operation.
6. No chemical costs are included.

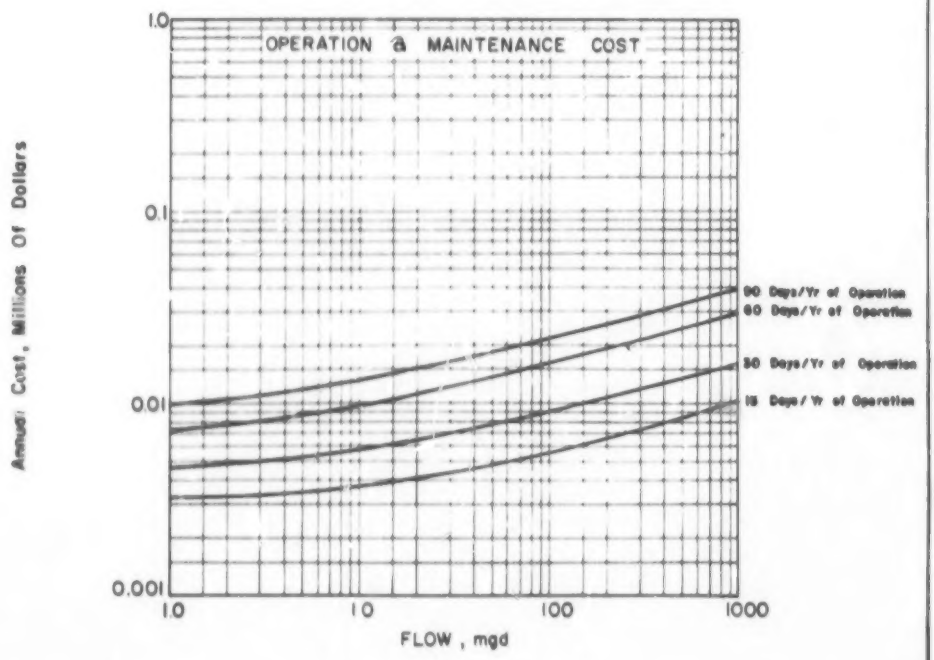
Process Performance: (When Used in Combination With Chemical Addition, Flocculation/Sedimentation)

	Typical Pollutant Removals, %
BOD_5	60 - 80
SS	80 - 95

References: 36, 37, 51

FIGURE H-27 HIGH-RATE FILTRATION (GRAVITY)





H.8 Municipal Wastewater Treatment Processes

H.8.1 Support Personnel:
Cost Curves, Figure H-28

H.8.2 Miscellaneous Structures:
Cost Curves, Figure H-29

FIGURE H-28

SUPPORT PERSONNEL

Relative Reliability: Level B

Design Basis:

1. Costs include the manpower required to support the operation of a wastewater treatment facility. These support functions include supervision and administration, clerical work, laboratory work, and administrative costs.

2. The labor costs are based on 1500 hour man-year. This includes a five-day work week; an average of 29 days for holidays, vacations and sick leave; and 6 1/2 hours of productive work per 8 hour day.

Reference: 45

FIGURE H-28 SUPPORT PERSONNEL

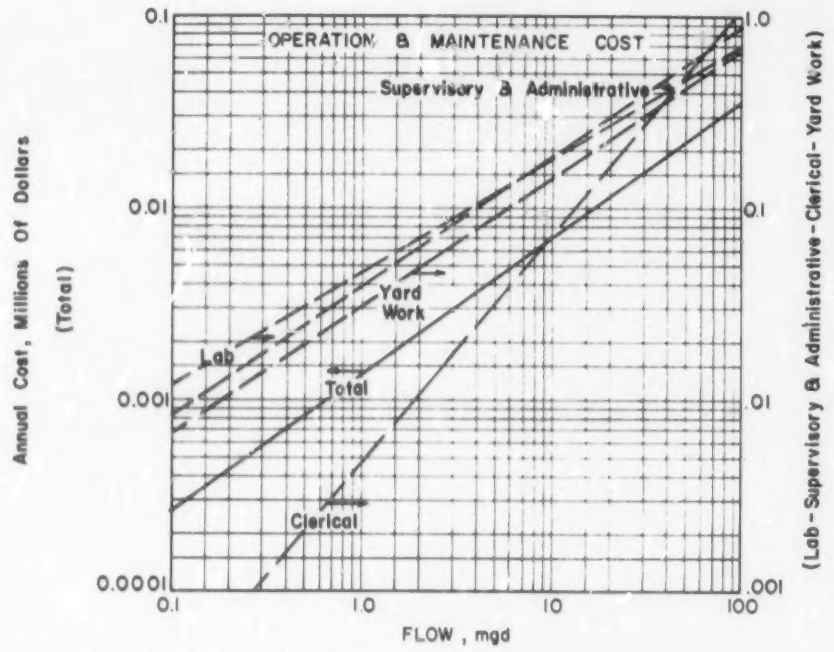


FIGURE H-29

MISCELLANEOUS STRUCTURES

Service Life: 50 years

Relative Reliability: Level B

Design Basis:

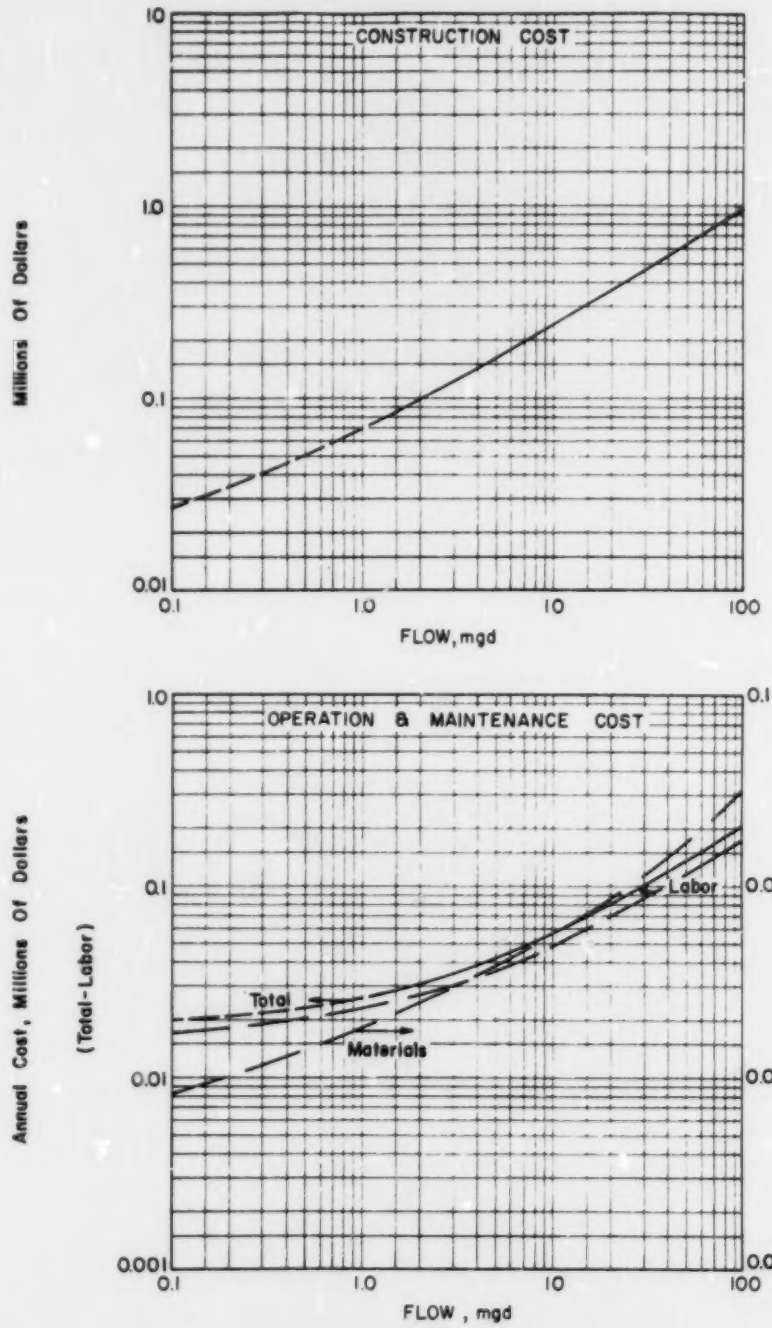
Construction cost includes:

a. Administrative offices.
b. Laboratories.
c. Shop and garage facilities.

Note: Full cost of miscellaneous structures might not be applicable for small-flow systems.

Reference: 3

FIGURE H-29 MISCELLANEOUS STRUCTURES



H.8.3 Wastewater Treatment Processes Cost Curves:

Figures H-30 through H-62

Raw Wastewater Characteristics:

BOD_5	210 mg/l
COD	400 mg/l
TSS	230 mg/l
NH_3-N	20 mg/l
TKN	30 mg/l
NO_3-N	0 mg/l
UOD	406 mg/l
Total-P	11 mg/l
Alkalinity (as $CaCO_3$)	300 mg/l
pH	7.3

FIGURE H-30

LOW-LIFT PUMP STATION

Service Life: 15 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include:
   a. Fully-enclosed wet well/dry well structure.
   b. Pumping equipment capable of meeting peak pumping requirements of 2 Q with largest unit out of service.
   c. Standby pumping facilities.
   d. Piping and valves within structure.
   e. Bar screens - mechanically cleaned.
2. Package pumping stations are used in a flow range of 50 to 1,200 gpm (0.072 to 1.73 mgd).
3. Curves developed for TDH = 10 feet.

Adjustment Factor:

To adjust operating power costs for TDH's other than 10 feet, enter curves at effective flow, Q_E

$$Q_E = Q_{DESIGN} \times \frac{TDH}{10}$$

References: 3, 7, 9

FIGURE H-30 LOW-LIFT PUMP STATION

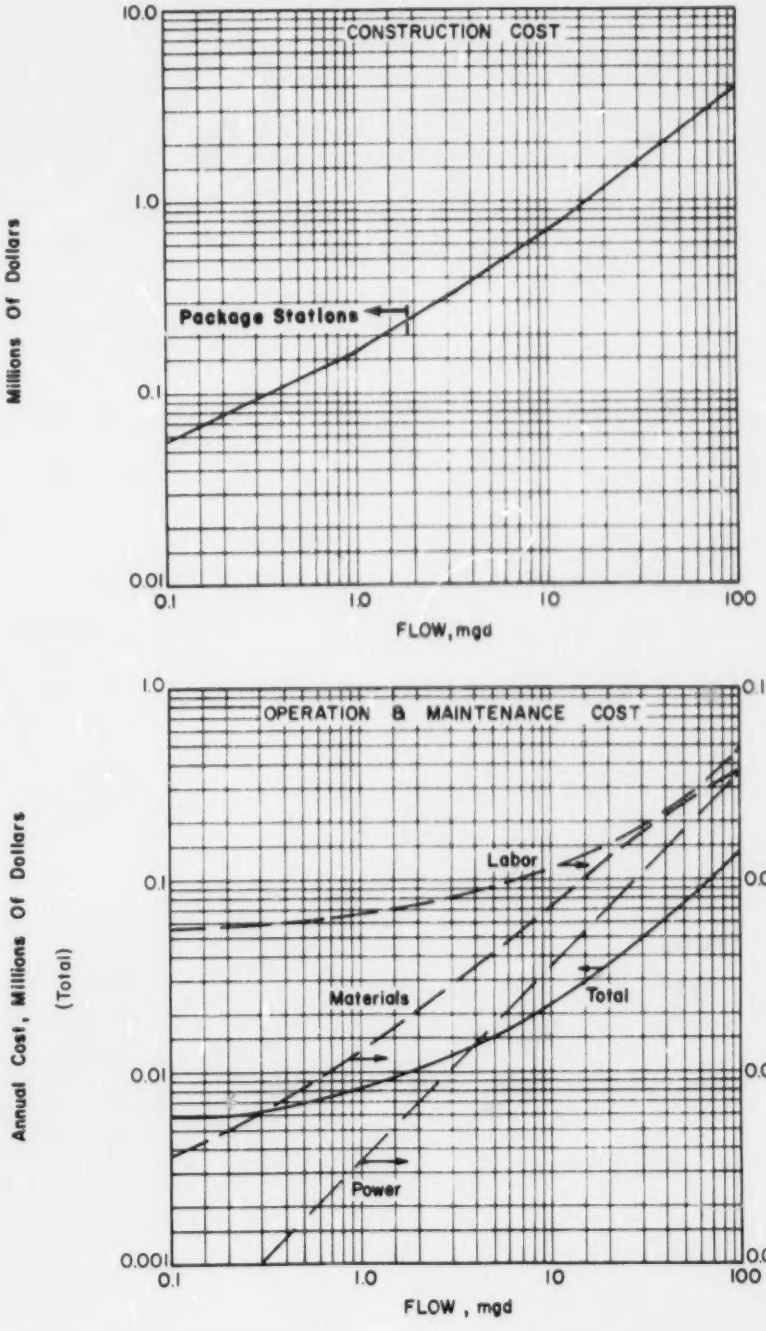


FIGURE H-31

PRELIMINARY TREATMENT

Service Life: 30 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include:

   a. Flow channels and superstructures.
   b. Bar screens (mechanical).
   c. Grinders for screenings.
   d. Gravity grit chamber with mechanical grit-handling equipment.
   e. Parshall flume and flow-recording equipment.

2. Operation and maintenance costs do not include cost for grit disposal.

3. Screenings 1-3 cu ft/mg.

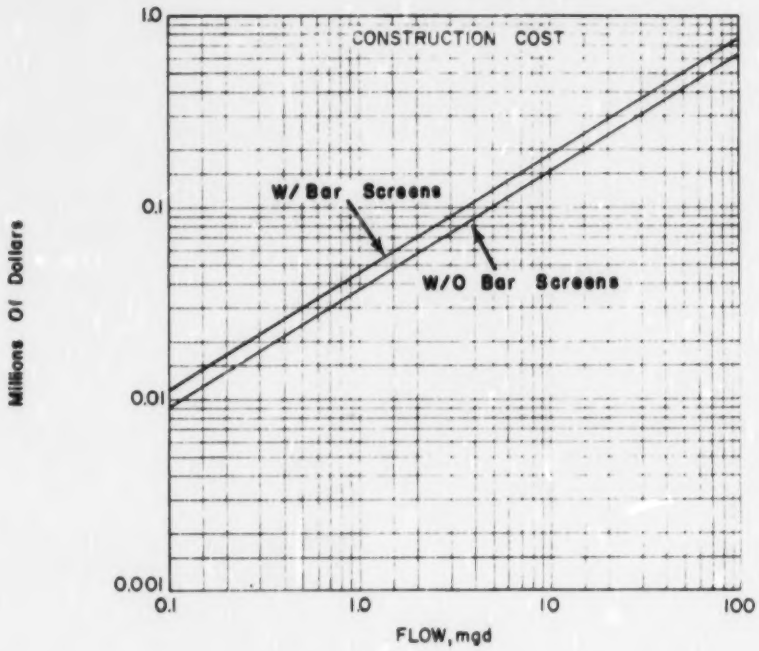
4. Grit 2-5 cu ft/mg.

5. If low-lift pumping is used prior to preliminary treatment, the cost for bar screens can be subtracted from the unit cost of preliminary treatment, because they are included in the low-lift pumping station.

Process Performance:

Suspended material greater than 5/8 inch and grit coarser than 65 mesh (0.208 mm) will be removed. However, removal of BOD and TSS by pre-treatment is assumed negligible.

FIGURE H-31 PRELIMINARY TREATMENT



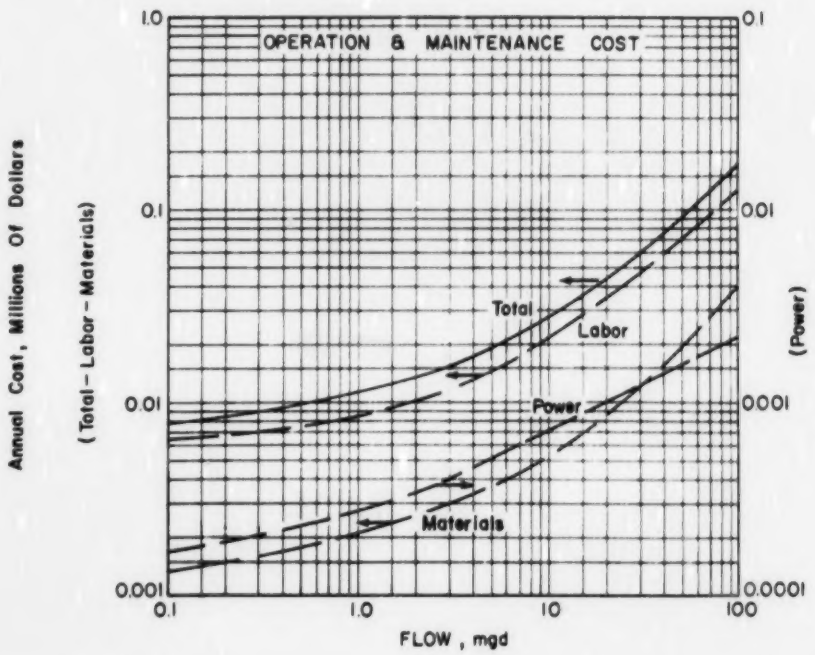


FIGURE H-32

FLOW EQUALIZATION

Service Life: 40 years

Relative Reliability: Level B

Design Basis:

1. Costs were derived for detention times of 0.5, 1.0, and 2.0 days based on offline storage at average flow conditions.

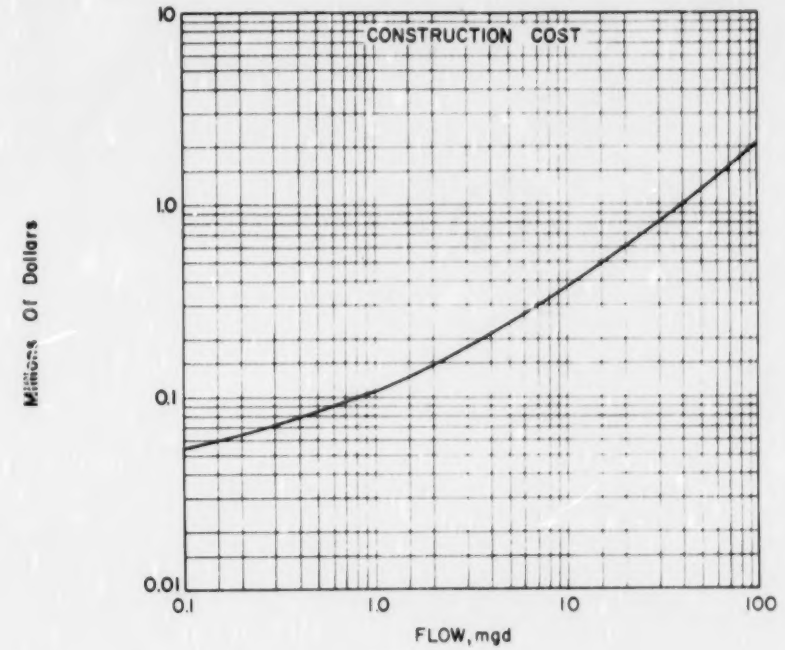
2. Mixing requirements = 20 to 40 hp/mg of storage volume.

3. Construction costs include basin and mechanical mixing equipment (pumping not included).

4. Construction costs are based on concrete basins for design flows less than 1 mgd and 6-inch concrete-lined earthen basins for design flows greater than 1 mgd.

References: 4, 5, 7

FIGURE H-32[1] FLOW EQUALIZATION
(DETENTION TIME = 0.5 DAYS)



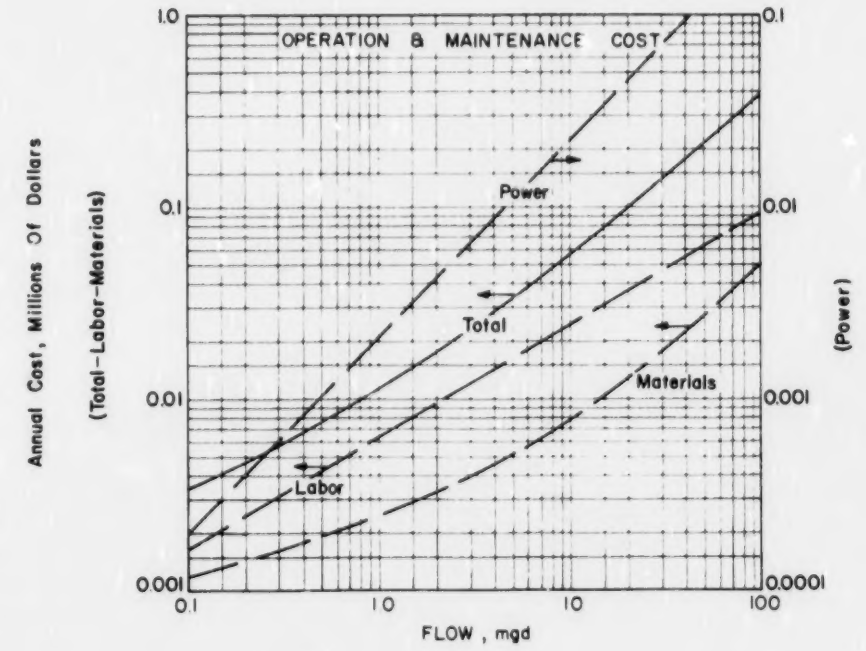
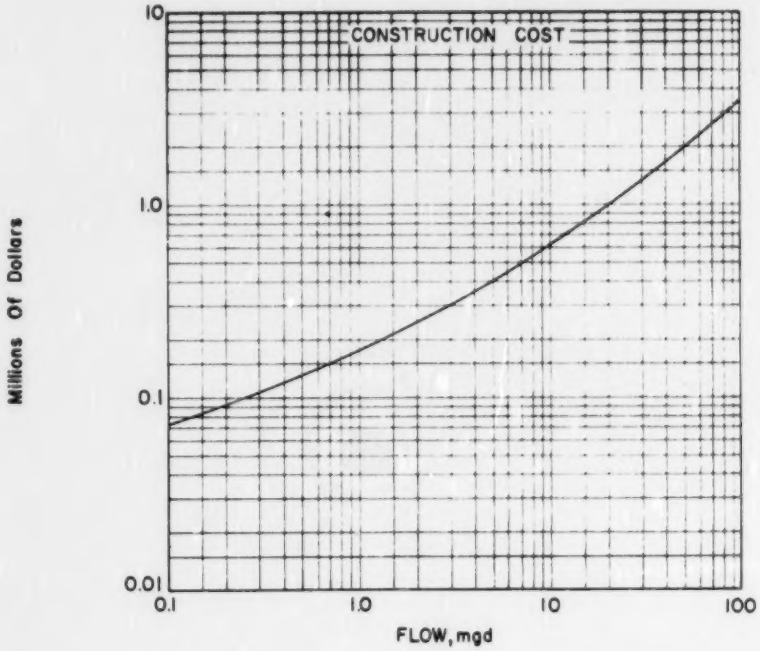


FIGURE H-32[2] FLOW EQUALIZATION
(DETENTION TIME = 1.0 DAYS)



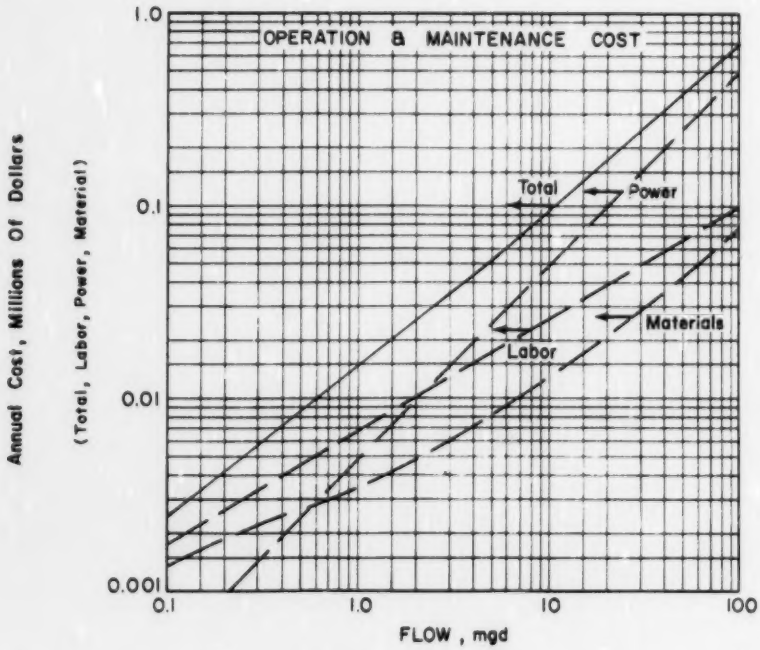
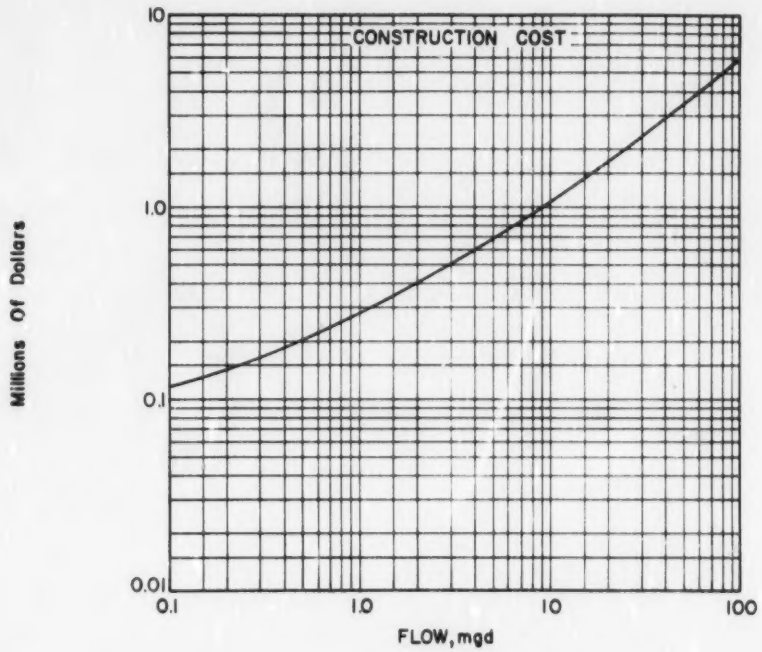


FIGURE H-32[3] FLOW EQUALIZATION
(DETENTION TIME = 2.0 DAYS)



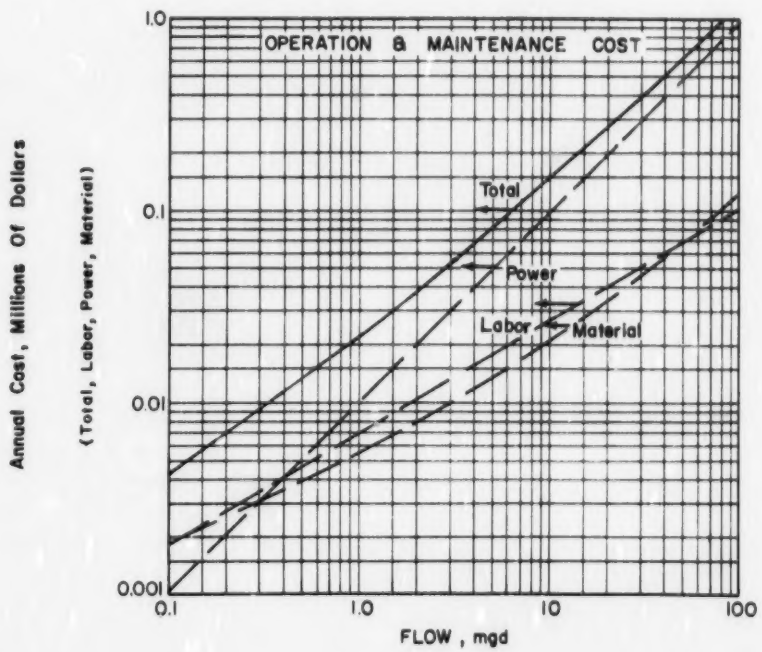


FIGURE H-33

PRIMARY CLARIFIER WITH SLUDGE PUMPS

Service Life: 50 years

Relative Reliability: Level B

Design Basis:

1. Clarifier designed for surface overflow rate of 800 gpd/sq ft (based on average Q).

2. Costs include primary sludge pumps. Sludge concentration of 4% solids. Pump head assumed as 10 ft TDH.

3. Process performance:

Wastewater Characteristics

	In	Out
BOD_5, mg/l	210	130
COD, mg/l	400	265
TSS, mg/l	230	100
Total-P, mg/l	11	9

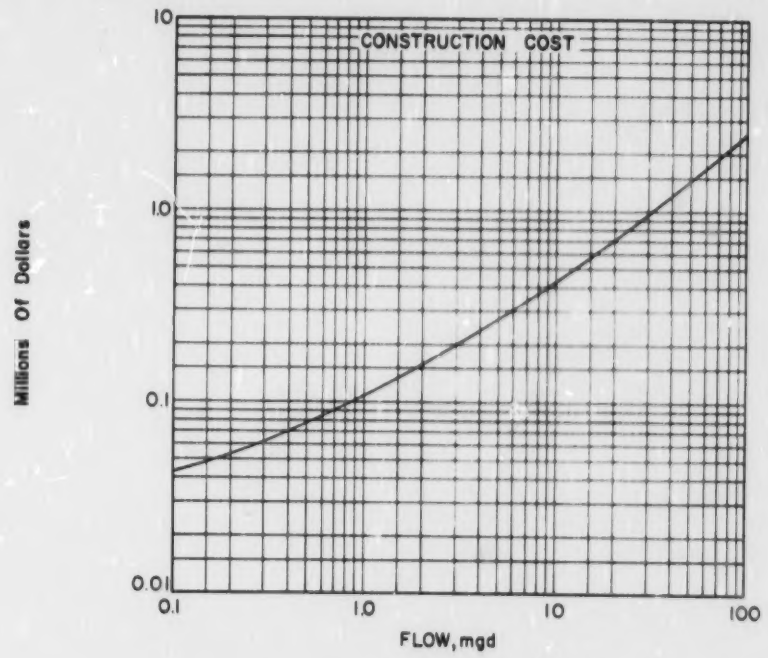
Adjustment Factor:

To adjust costs for alternative surface overflow rate, enter flow at effective flow (Q_E)

$$Q_E = Q_{DESIGN} \times \frac{800 \text{ gpd/sq ft}}{\text{New Design Surface Overflow Rate}}$$

References: 9, 24

FIGURE H-33 PRIMARY CLARIFIER WITH SLUDGE PUMPS



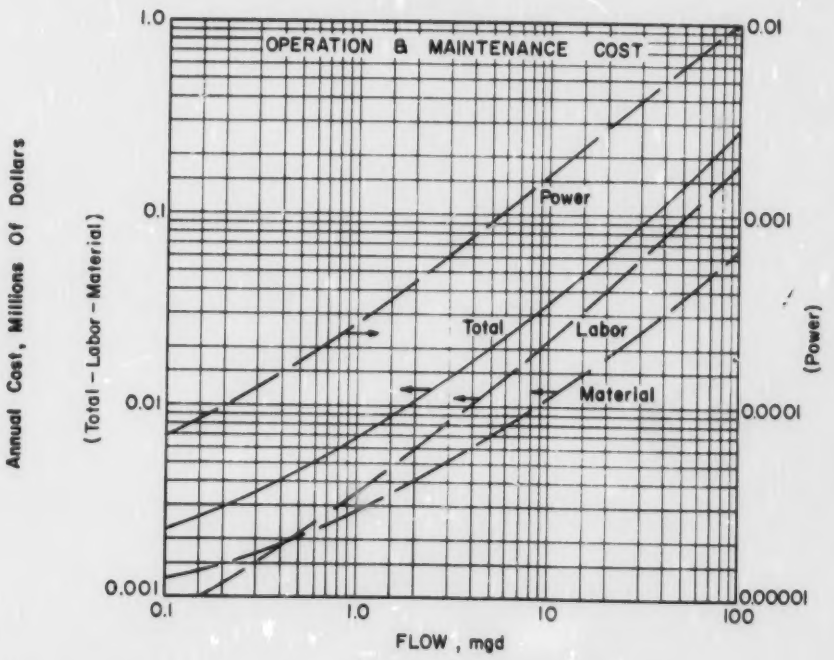


FIGURE H-34

CONVENTIONAL ACTIVATED SLUDGE AERATION WITH DIFFUSED AIR

Service Life: 40 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include costs for basins, air supply equipment and piping, and blower building. Clarifier and recycle pumps are not included. Clarifier costs are found in Figure H-42.
2. Diffused aeration.
3. 1.2 lbs O_2 supplied per pound of BOD_5 removed.
4. MLVSS = 2,000 mg/l.
5. F/M = 0.5.
6. Detention time = 6 hours.
7. Process performance:

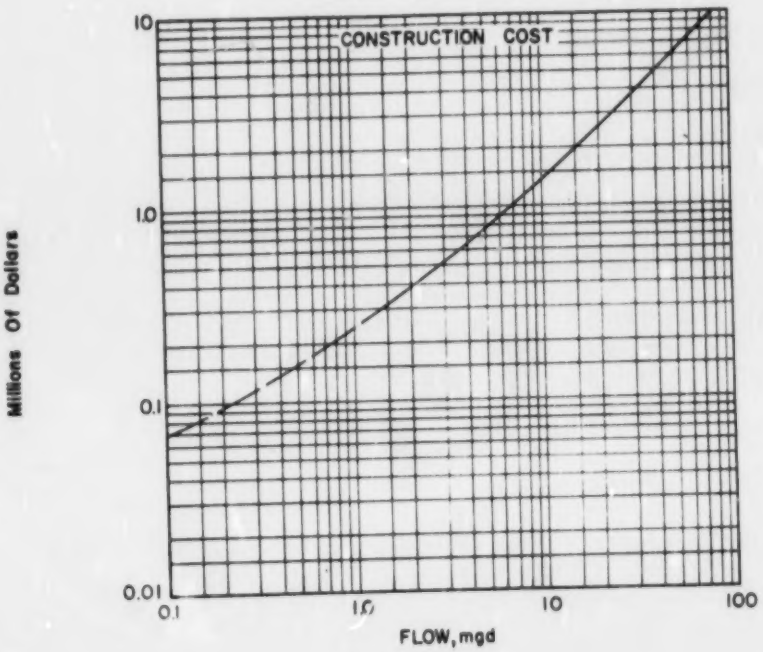
Wastewater Characteristics

	In	Out*
BOD_5, mg/l	130	20
COD, mg/l	265	45
TSS, mg/l	100	20
Total-P, mg/l	9	7
NH_3-N, mg/l	20	17
TKN, mg/l	30	18

*Following clarification

References: 3, 7

FIGURE H-34 CONVENTIONAL ACTIVATED SLUDGE AERATION WITH DIFFUSED AIR



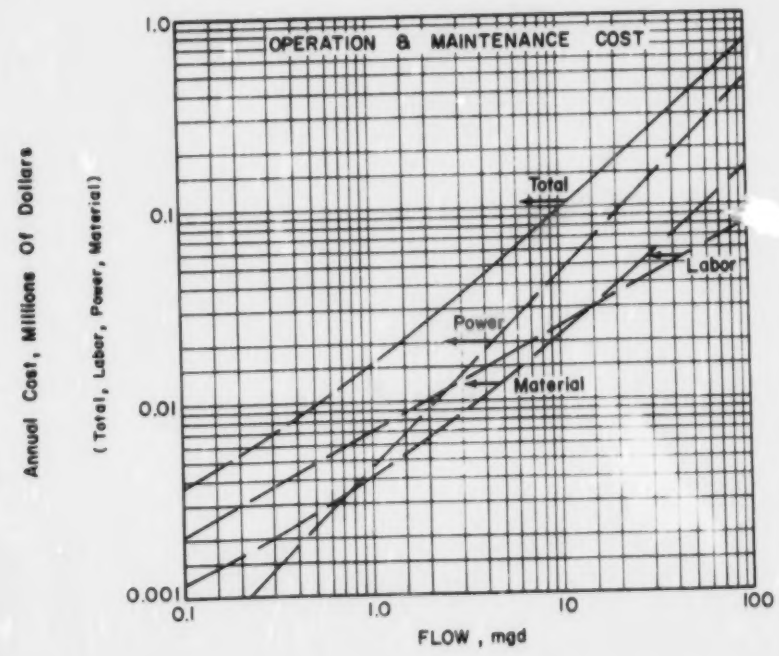


FIGURE H-35

ACTIVATED SLUDGE AERATION WITH PURE OXYGEN

Service Life: 30 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include: dissolution equipment, oxygen generators and liquid oxygen feed/storage facilities instrumentation (where applicable), and licensing fees.
2. Oxygen was assumed to be delivered as liquid oxygen for plants from 0.1 to 1 mgd size. For plants from 1.0 to 100 mgd, oxygen was assumed to be generated on-site.
3. 1.2 lbs O_2 supplied per pound of BOD_5 removed.
4. MLVSS = 4,000 mg/1.
5. Detention time = 5 hours.
6. Process performance:

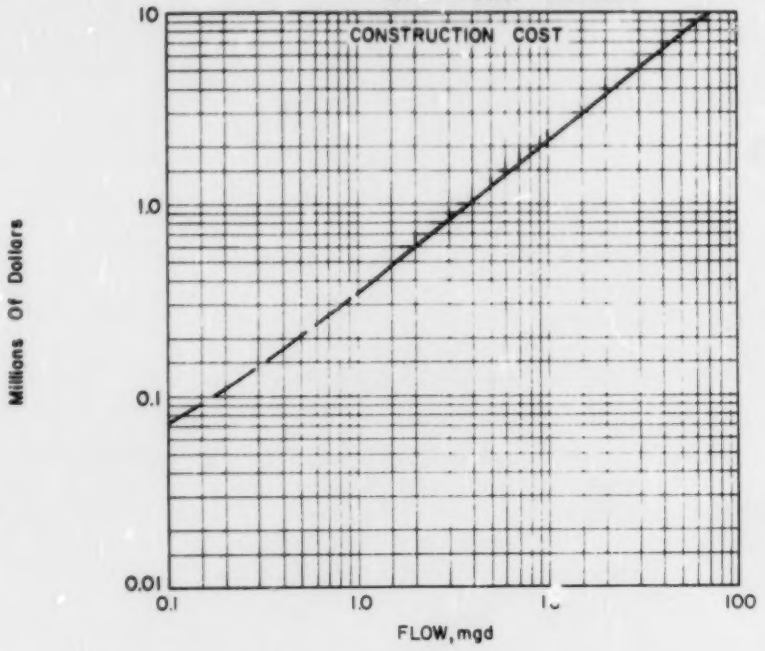
Wastewater Characteristics

	In	Out*
BOD_5, mg/1	130	20
COD, mg/1	265	40
TSS, mg/1	100	25
Total-P, mg/1	9	7
NH_3-N, mg/1	20	17
TKN, mg/1	30	18

*Following clarification

References: 39, 40, 41

FIGURE H-35 ACTIVATED SLUDGE AERATION WITH PURE OXYGEN



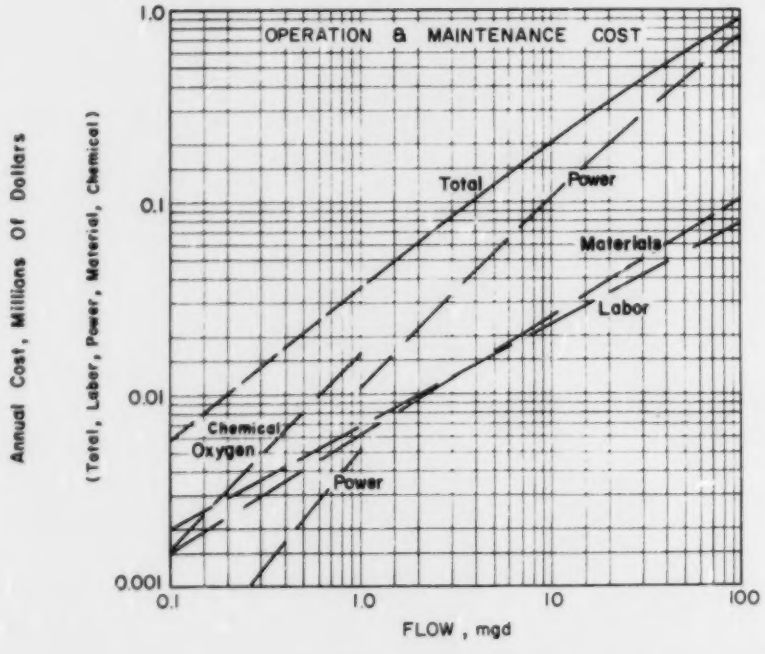


FIGURE H-36

HIGH-RATE TRICKLING FILTER

Service Life: 50 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include: circular filter units with rotating distributor arms, synthetic media (6 feet-deep), and underdrains. Clarifiers and recycle equipment not included. (See Figure H-43.)

2. Organic loading rate: High Rate = 45 lb BOD_5/day/1,000 cu ft.

3. Hydraulic loading rate: High Rate = 30.2 mgad (693 gpd/sq ft) @ 3:1 recycle rate.

4. Electrical power not required (included in clarifier cost).

5. Process performance:

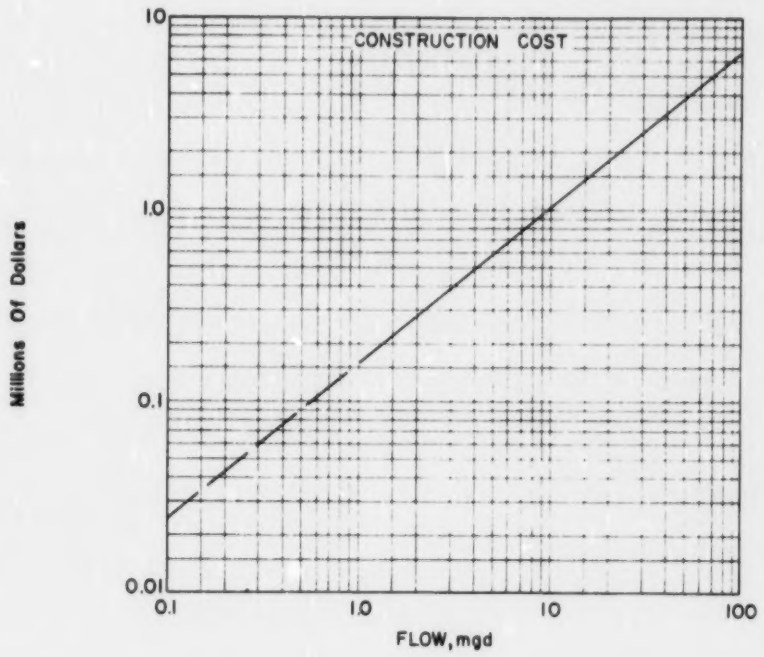
Wastewater Characteristics

	In	Out*
BOD_5, mg/l	130	45
COD, mg/l	265	90
TSS, mg/l	100	60
Total-P, mg/l	9	8
NH_3-N, mg/l	20	17
TKN, mg/l	30	18

*Following clarification

References: 3, 5, 6, 7, 30

FIGURE H-36 HIGH-RATE TRICKLING FILTER



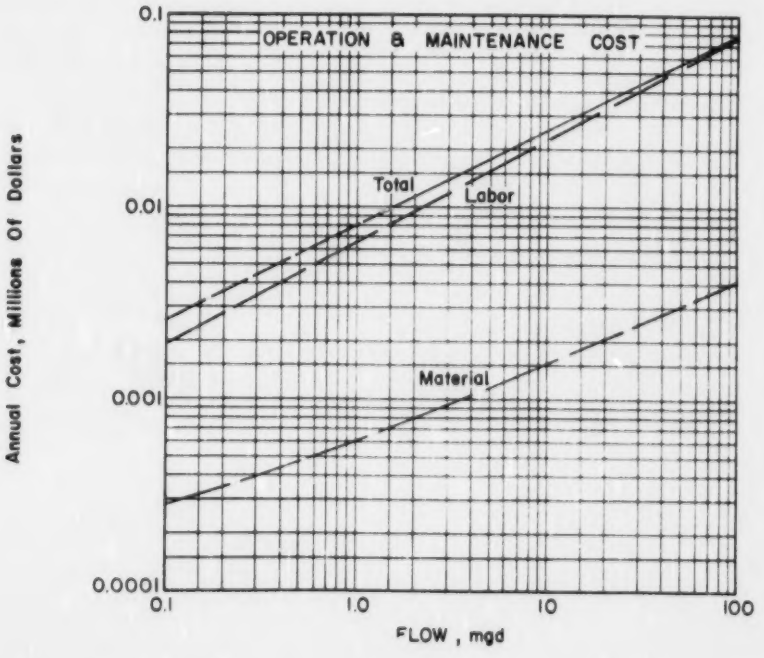


FIGURE H-37

LOW-RATE TRICKLING FILTER

Service Life: 50 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include: circular filter units with rotating distributor arms, rock media (6 feet-deep), and underdrains. Clarifiers not included. (See Figure H-43.)
2. Organic loading rate: Low Rate = 15 lb BOD_5/day/1,000 cu ft.
3. Hydraulic loading rate: Low Rate = 2.4 mgad (55 gpd/sq ft).
4. Electrical power not required (included in clarifier cost).
5. No pump station included.
6. Process performance:

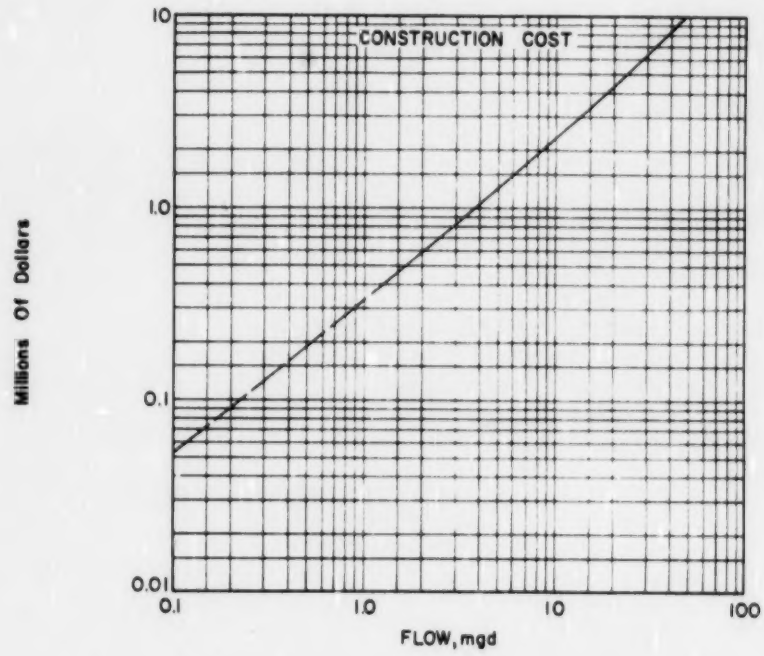
Wastewater Characteristics

	In	Out*
BOD_5, mg/l	130	30
COD, mg/l	265	60
TSS, mg/l	100	60
Total-P, mg/l	9	8
NH_3-N, mg/l	20	2
NO_3^--N, mg/l	30	18

*Following clarification at temperature above 15°C.

References: 3, 5, 6, 7, 30

FIGURE H-37 LOW-RATE TRICKLING FILTER



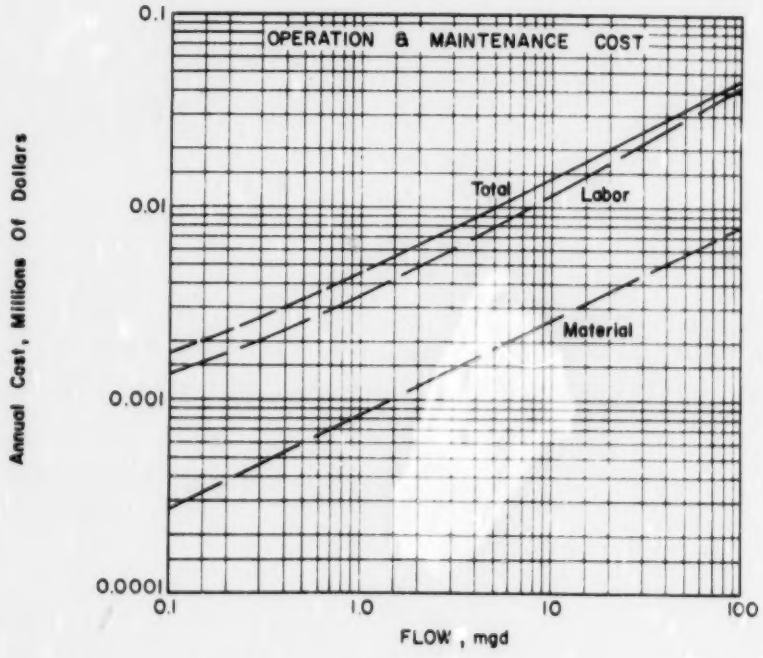


FIGURE H-38

AERATED LAGOONS

Service Life: 30 years

Relative Reliability: Level B

Design Basis:

1. Average detention time = 7 days.
2. 15-ft water depth.
3. Horsepower required: 30 to 40 hp/mg.
4. Floating mechanical aerators.
5. Construction cost includes:
   a. Excavation, embankment, and seeding of lagoon/slopes (3 cells).
   b. Service road and fencing.
   c. Riprap embankment protection.
   d. Hydraulic control works.
   e. Aeration equipment and electrical equipment.
6. Process performance:

Wastewater Characteristics

	In	Out
BOD_5, mg/l	210	25
COD, mg/l	400	50
TSS, mg/l	230	40
Total-P, mg/l	11	8
NH_3-N, mg/l	20	18

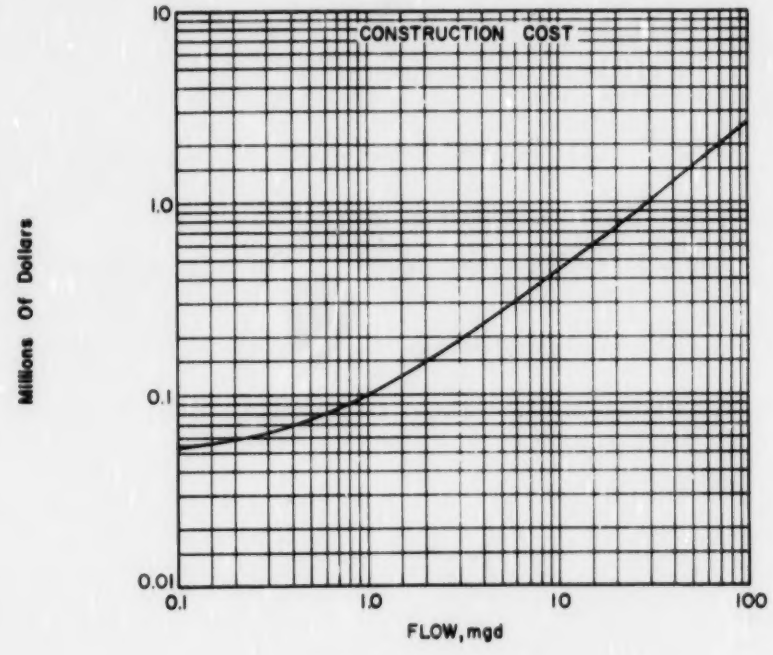
Adjustment Factor:

To adjust construction cost for detention time other than above, enter curve at effective flow (Q_E)

$$Q_E = Q_{DESIGN} \times \frac{\text{New Design Detention Time}}{7 \text{ Days}}$$

References: 27, 43

FIGURE H-38 AERATED LAGOONS



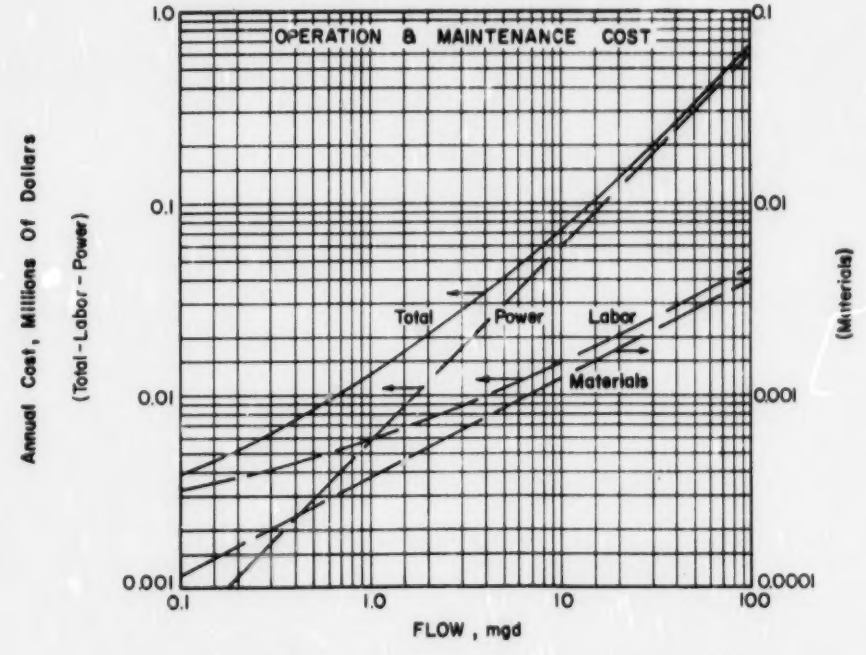


FIGURE H-39

ROTATING BIOLOGICAL CONTACTORS

Service Life: 30 years

Relative Reliability: Level B

Design Basis:

1. Construction cost includes:

   a. RBC shafts; standard media, 100,000 sq ft/shaft.
   b. Motor drives - 5 hp/shaft.
   c. Molded fiberglass covers.
   d. Reinforced concrete basins.

2. Cost does not include final clarifiers. (See Figure H-42.)

3. Loading rate:

   a. 1.0 gpd/sq ft, w/o nitrification.
   b. 0.5 gpd/sq ft, w/nitrification.

4. Process performance:

	Wastewater Characteristics		
	In	Out	
		w/o Nitrification	w/Nitrification
BOD_5, mg/l	130	20	15
COD, mg/l	265	45	35
TSS, mg/l	100	25	25
Total-P, mg/l	9	7	8
NH_3-N, mg/l	20	17	2

Reference: 48

FIGURE H-39 ROTATING BIOLOGICAL CONTACTOR (W/NITRIFICATION)

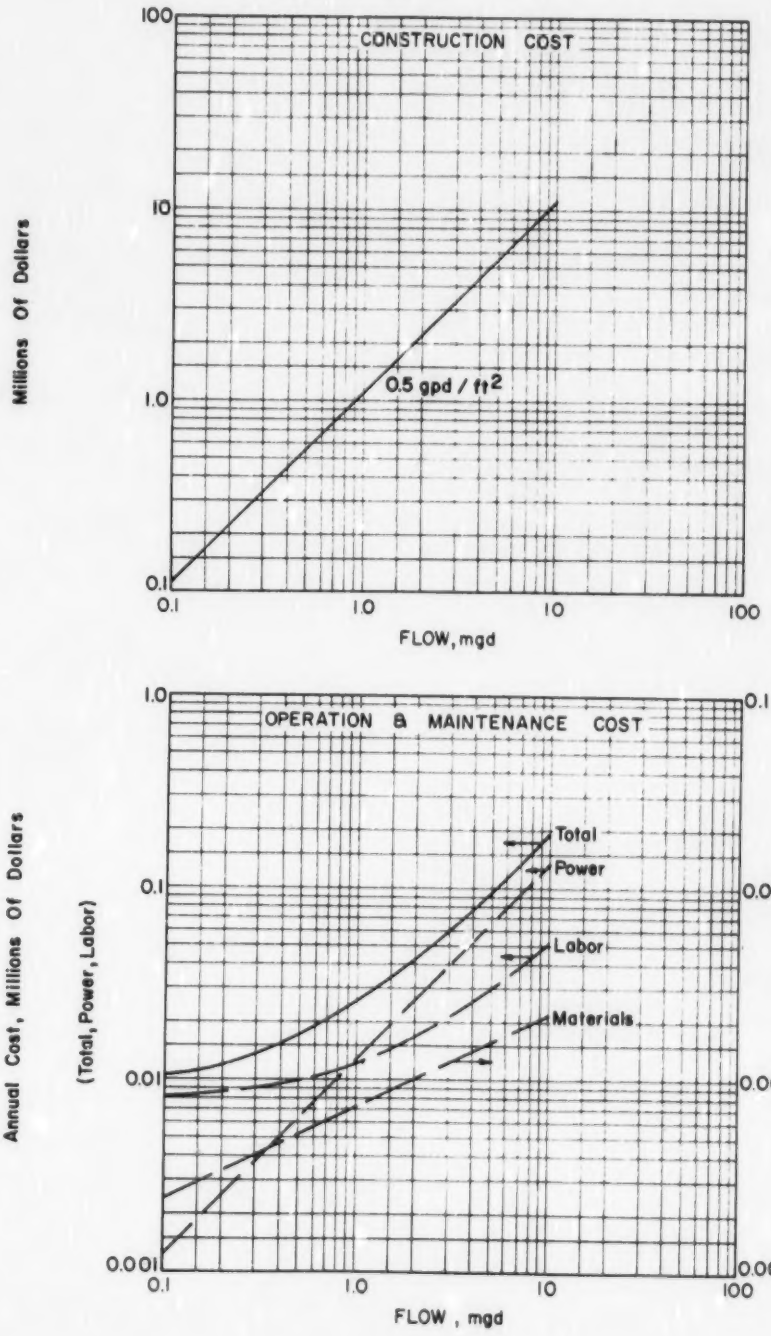


FIGURE H-39

ROTATING BIOLOGICAL CONTACTORS

Service Life: 30 years

Relative Reliability: Level B

Design Basis:

1. Construction cost incudes:

   a. RBC shafts; standard media, 100,000 sq ft/shaft.
   b. Motor drives - 5 hp/shaft.
   c. Molded fiberglass covers.
   d. Reinforced concrete basins.

2. Cost does not include final clarifiers. (See Figure H-42.)

3. Loading rate:

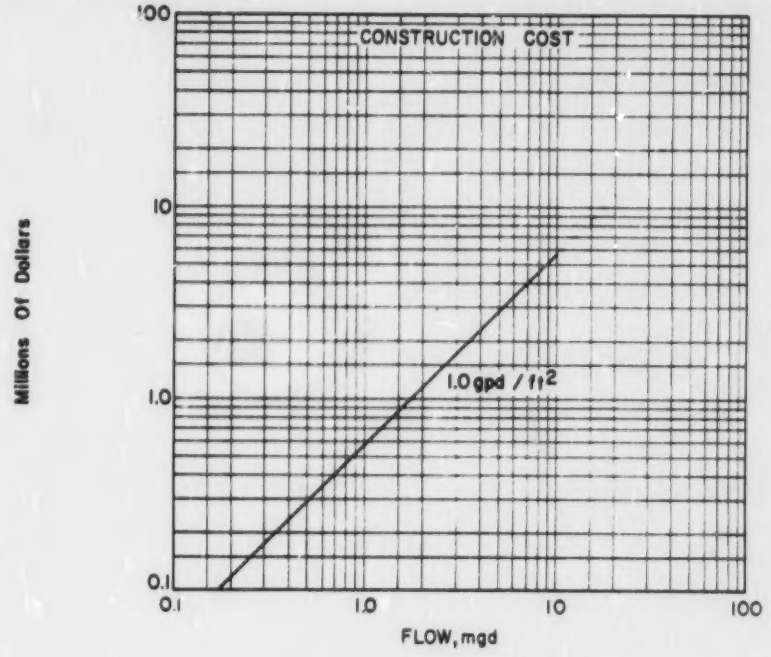
   a. 1.0 gpd/sq ft, w/o nitrification.
   b. 0.5 gpd/sq ft, w/nitrification.

4. Process performance:

	Wastewater Characteristics		
	In	Out	
		w/o Nitrification	w/Nitrification
BOD_5, mg/l	130	20	15
COD, mg/l	265	45	35
TSS, mg/l	100	25	25
Total-P, mg/l	9	7	8
NH_3-N, mg/l	20	17	2

Reference: 48

FIGURE H-39 ROTATING BIOLOGICAL CONTACTOR (W/O NITRIFICATION)



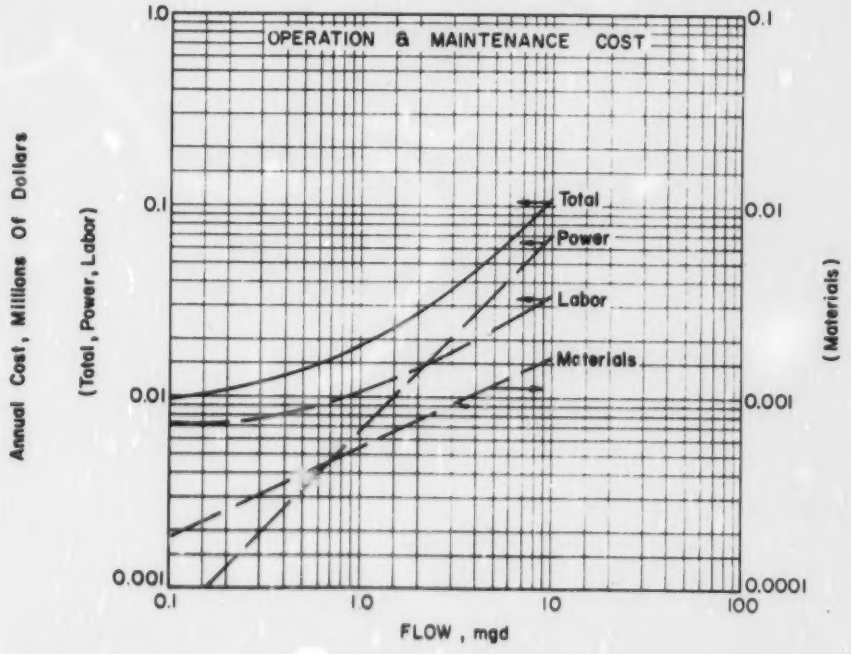


FIGURE H-40

FACULTATIVE LAGOONS

Service Life: 50 years

Relative Reliability: Level B

Design Basis:

1. Warm climate - lagoon loading of 40 lb BOD_5/acre/day.
2. Cool climate (Northern U.S.) - lagoon loading of 20 lb BOD_5/acre/day.
3. Water Depth = 4 ft.
4. Construction costs include:
   a. Excavating, grading, and other earthwork required for normal subgrade preparation.
   b. Service roads.
   c. Costs do not include land and pumping.
5. Process performance:

Wastewater Characteristics

	In	Out	
BOD_5, mg/L	210	30	
COD, mg/1	400	100	
TSS, mg/1	230	60	
Total-P, mg/1	11	8	
NH_3-N, mg/1	20	15	(cool climate)
		1	(warm climate)

Adjustment Factor:

To adjust costs for loadings other than those above, enter curve at effective flow (Q_E)

Warm Climates:

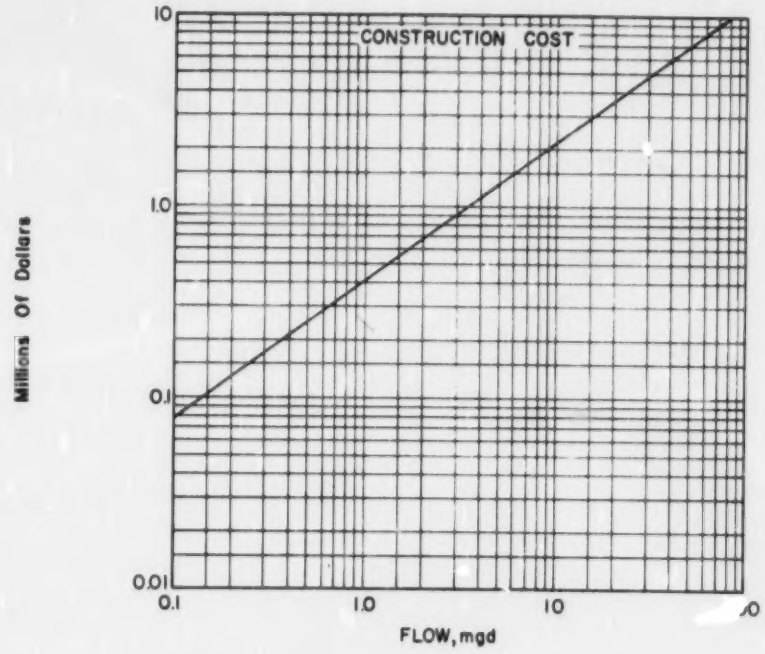
$$Q_E = Q_{DESIGN} \times \frac{40 \text{ lb } BOD_5/\text{acre/day}}{\text{New Design Loading}}$$

Cool Climates:

$$Q_E = Q_{DESIGN} \times \frac{20 \text{ lb } BOD_5/\text{acre/day}}{\text{New Design Loading}}$$

References: 3, 5, 28

FIGURE H-40[1] FACULATIVE LAGOON (Warm Climates)



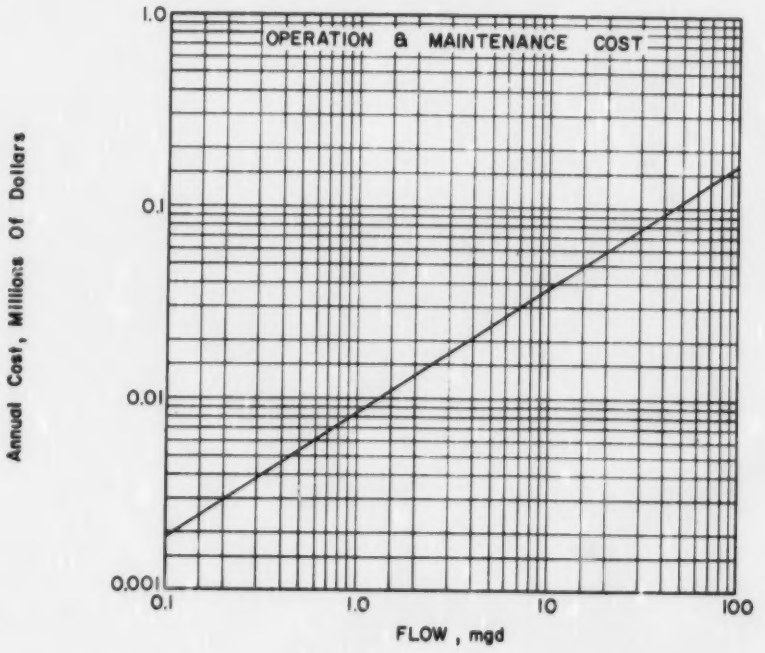


FIGURE H-40

FACULTATIVE LAGOONS

Service Life: 50 years

Relative Reliability: Level B

Design Basis:

1. Warm climate - lagoon loading of 40 lb BOD_5/acre/day.
2. Cool climate (Northern U.S.) - lagoon loading of 20 lb BOD_5/acre/day.
3. Water Depth = 4 ft.
4. Construction costs include:
   a. Excavating, grading, and other earthwork required for normal subgrade preparation.
   b. Service roads.
   c. Costs do not include land and pumping.
5. Process performance:

Wastewater Characteristics			
	In	Out	
BOD_5, mg/l	210	30	
COD, mg/l	400	100	
TSS, mg/l	230	60	
Total-P, mg/l	11	8	
NH_3-N, mg/l	20	15	(cool climate)
		1	(warm climate)

Adjustment Factor:

To adjust costs for loadings other than those above, enter curve at effective flow (Q_E)

Warm Climates:

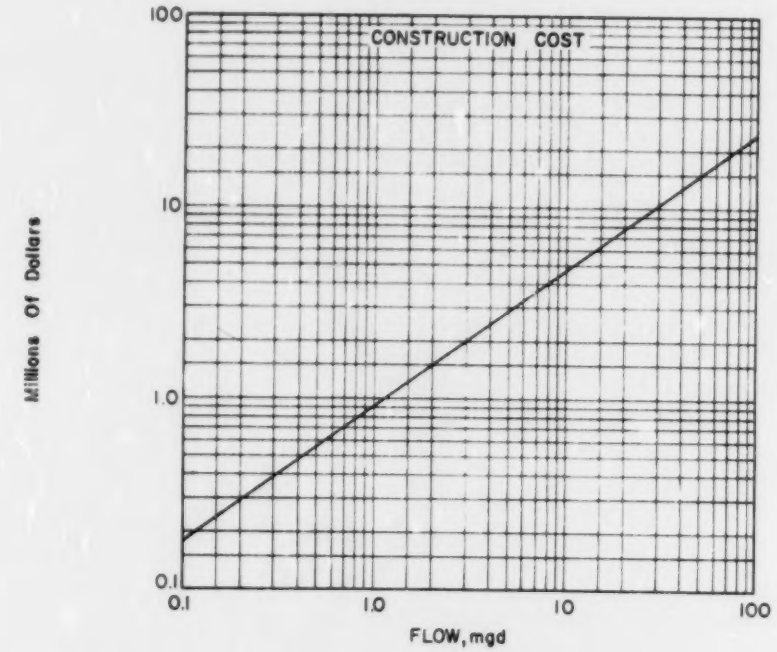
$$Q_E = Q_{DESIGN} \times \frac{40 \text{ lb } BOD_5/\text{acre/day}}{\text{New Design Loading}}$$

Cool Climates:

$$Q_E = Q_{DESIGN} \times \frac{20 \text{ lb } BOD_5/\text{acre/day}}{\text{New Design Loading}}$$

References: 3, 5, 28

FIGURE H-40[2] FACULATIVE LAGOON (Cool Climates)



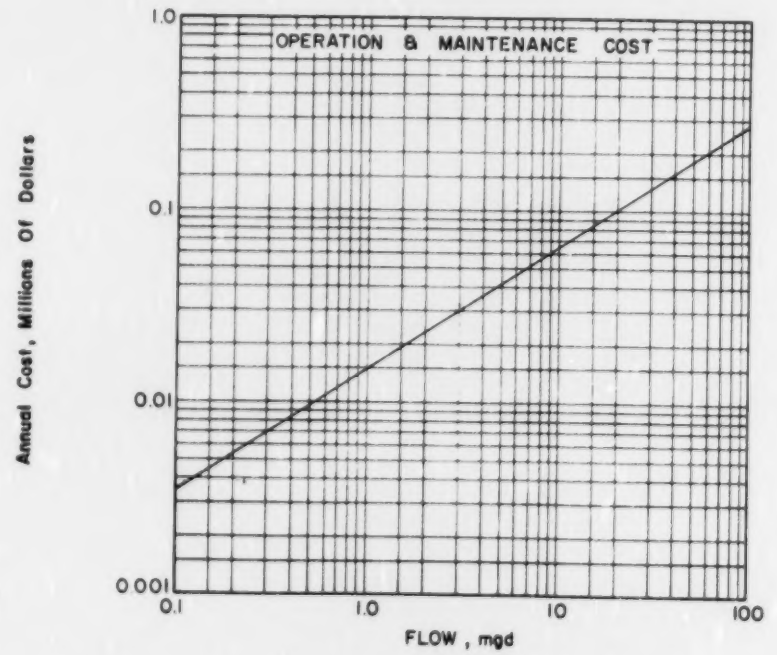


FIGURE H-41

HIGH-RATE ACTIVATED SLUDGE AERATION (COMPLETE MIX)

Service Life: 40 years

Relative Reliability: Level B

Design Basis:

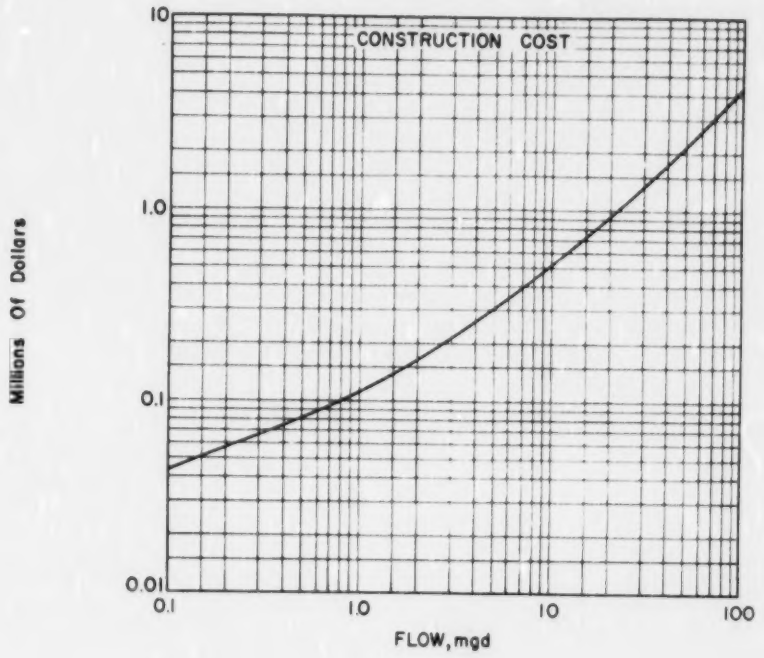
1. Construction cost includes cost for basins, air supply equipment and piping, and a blower building. Clarifier and recycle pumps are not included. (See Figure H-42.)
2. Basins sized with 50 percent recycle flow.
3. Detention time = 3 hours.
4. F/M = 1.5.
5. 0.7 lbs O_2 applied per pound BOD_5 removed.
6. MLVSS = 2,000 mg/l.
7. Process Performance:

Wastewater Characteristics

	In	Out
BOD_5, mg/l	130	40
COD, mg/l	265	80
TSS, mg/l	100	35
Total-P, mg/l	9	8
NH_3-N, mg/l	20	19

References: 3, 7

FIGURE H-41 HIGH-RATE ACTIVATED SLUDGE - AERATION - COMPLETE MIX
(Two - Hour Detention Time)



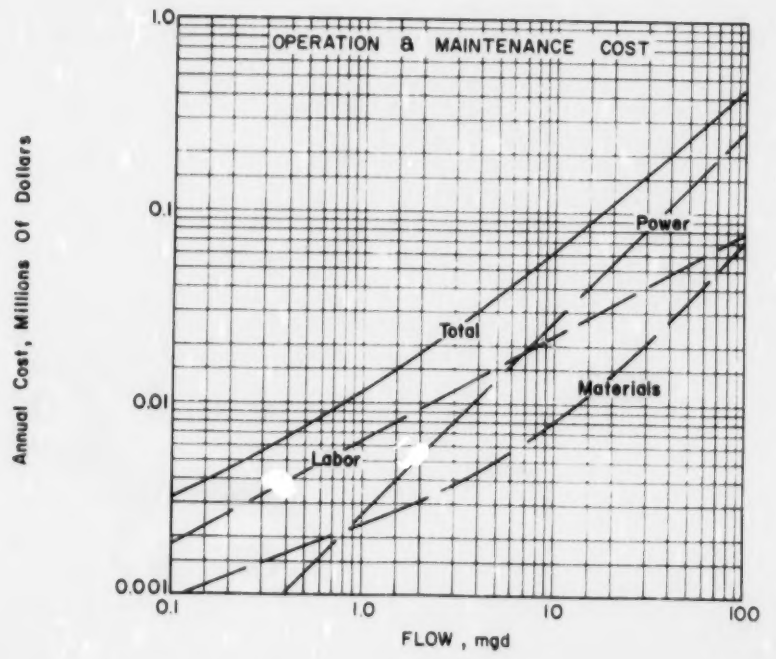


FIGURE H-42

FINAL CLARIFIER (FLOCCULATOR TYPE)

Service Life: 40 years

Relative Reliability: Level B

Design Basis:

1. Flocculator-type clarifier.
2. Overflow rate of 600 gpd/sq ft used for development of costs.
3. Costs include sludge return and waste pumps. Sludge concentration of 1 percent solids. Pump TDH at 10 ft. Spare pumps included as necessary. Pump capacity 350 gpm/mgd of plant capacity. Nonclog centrifugal pumps.
4. Rectangular units when surface area is less than 500 sq ft. Circular units when surface area is greater than 500 sq ft.
5. Maximum clarifier diameter = 200 ft.
6. Clarifier performance: See performance characteristics predicted for processes that precede clarifiers.

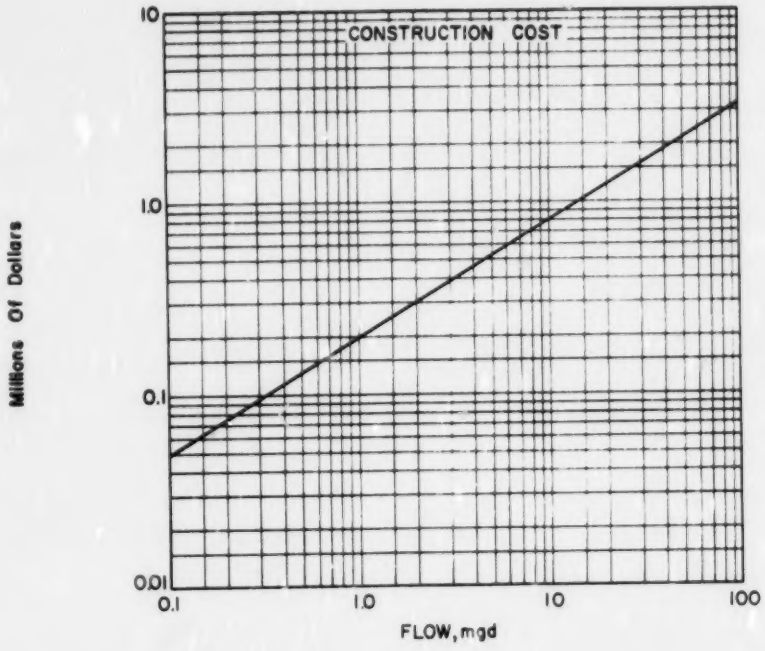
Adjustment Factor:

To adjust capital cost for alternative overflow rates, enter the curve at effective flow (Q_E)

$$Q_E = Q_{DESIGN} \times \frac{600 \text{ gpd/sq ft}}{\text{New Design Overflow Rate}}$$

References: 6, 7, 9, 24

FIGURE H-42 FINAL CLARIFIER (FLOCCULATOR TYPE)



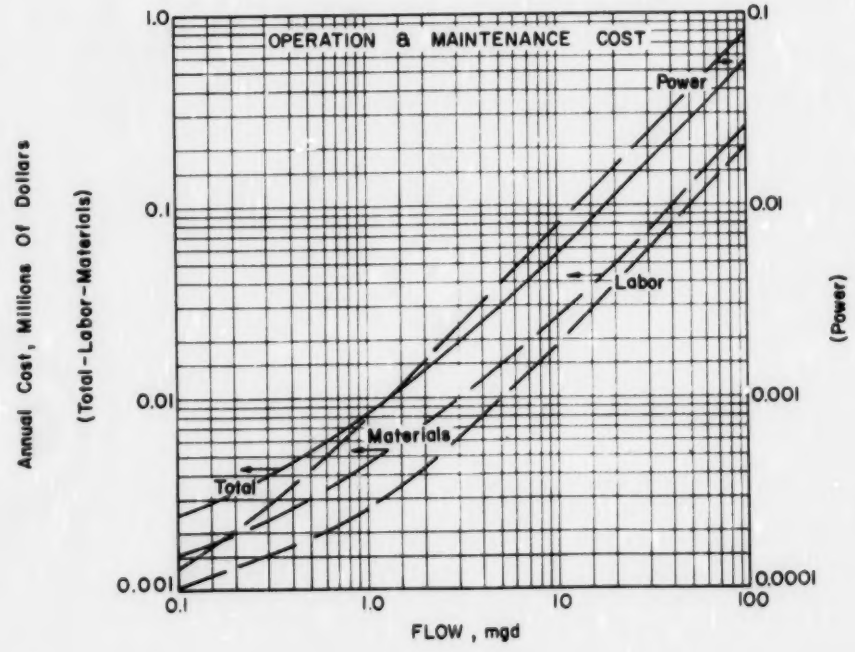


FIGURE H-43

CLARIFIER FOR HIGH-RATE TRICKLING FILTER
(INCLUDES RECYCLE PUMPS)

Service Life: 40 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include: sludge pumps, effluent recycle pumps, clarifier mechanisms and internal piping.
2. Overflow rate = 800 gpd/sq ft at average design flow.
3. Recycle pumping capacity = 3 times average wastewater flow.
4. Curve is to be used in conjunction with high-rate trickling filter only.
5. Rectangular units when surface area is less than 500 sq. ft. Circular units when surface area flow is greater than 500 sq ft.
6. Maximum clarifier diameter = 200 ft.
7. Clarifier performance: see predicted performance of high-rate trickling filter.

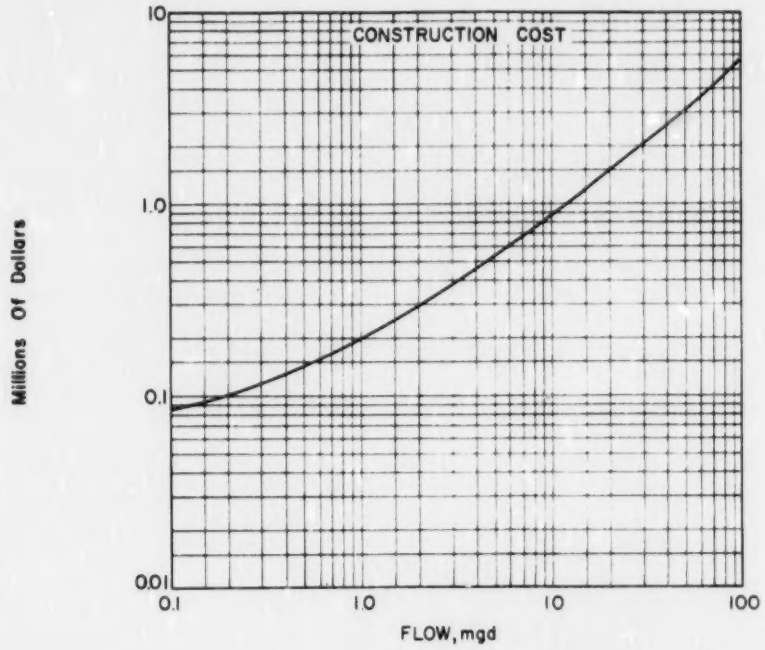
Adjustment Factor:

To adjust construction cost for alternative loading rates, enter curve at effective flow (Q_E)

$$Q_E = Q_{DESIGN} \times \frac{800 \text{ gpd/sq ft}}{\text{New Design Overflow Rate}}$$

References: 3, 6

FIGURE H-43 CLARIFIER FOR HIGH RATE TRICKLING FILTER
(INCLUDES RECYCLE PUMPS)



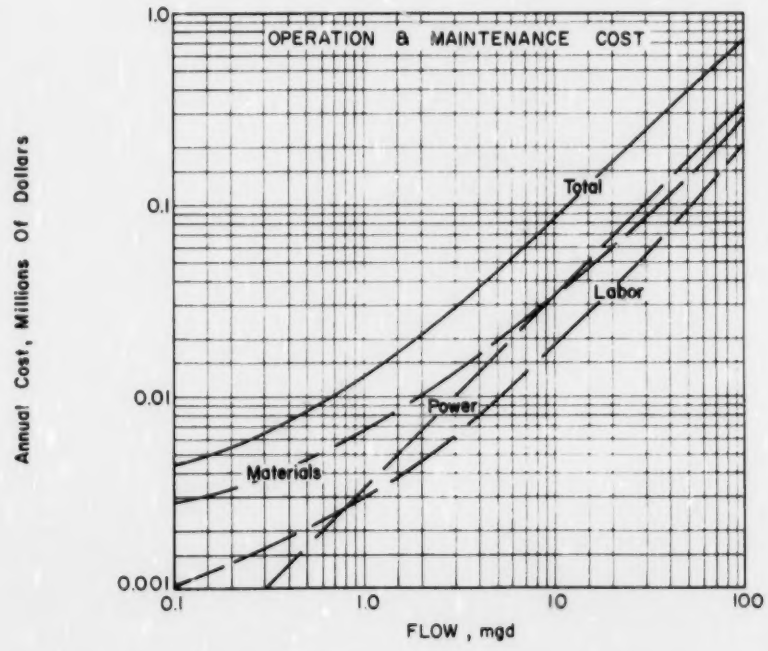


FIGURE H-44

ACTIVATED SLUDGE/NITRIFICATION (SINGLE STAGE)

Service Life: 40 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include aeration tanks and aeration devices, but not necessarily clarifiers and sludge pumps. (See Figure H-42.)
2. The activated sludge system is assumed to be a plug flow. The nitrification takes place in the latter portions of the basin.
3. The detention time is assumed to be 10 hours.
4. The aeration and mixing are accomplished by diffused air.
5. Oxygen requirements: 1.5 lbs O_2/lb BOD_5 removed plus 4.6 lbs O_2/lb NH_3 oxidized.
6. MLVSS = 1,500 mg/l.
7. SRT = 15 days.
8. Process performance:

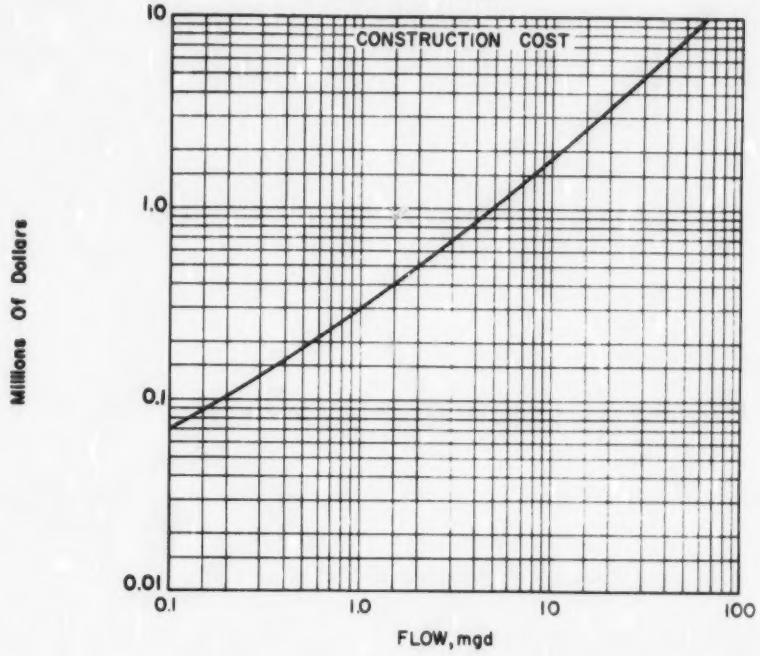
Wastewater Characteristics

	In	Out*
BOD_5, mg/l	140	10
COD, mg/l	265	35
TSS, mg/l	100	20
Total-P, mg/l	9	8
NH_3-N, mg/l	20	2
NO_3-N, mg/l	0	18

*Following clarification.

References: 3, 7, 9

FIGURE H-44 ACTIVATED SLUDGE / NITRIFICATION (SINGLE STAGE)



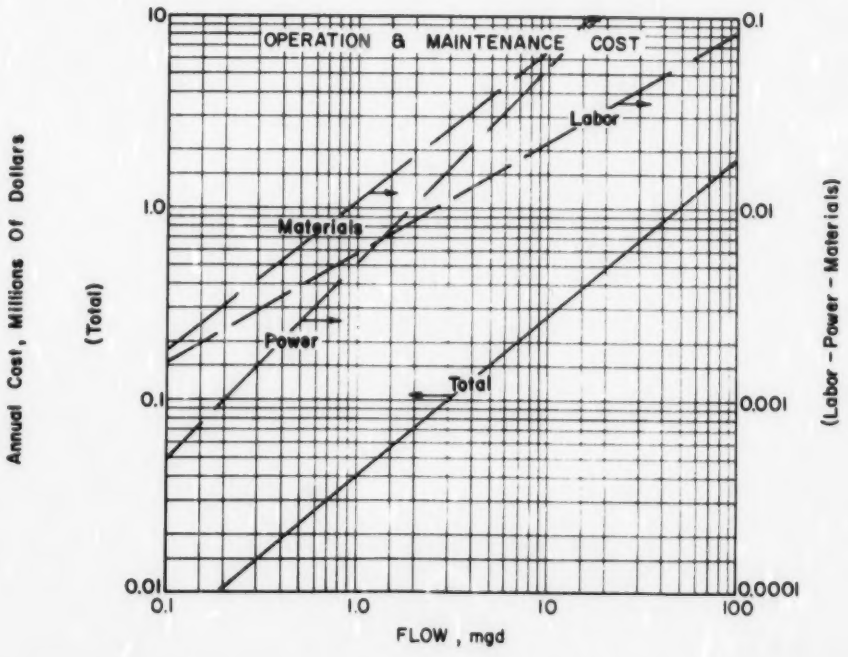


FIGURE H-45

SEPARATE NITRIFICATION (WITH CLARIFIER)

Service Life: 40 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include nitrification tanks, aeration devices, clarifiers, and sludge recycle and waste pumps, but not pH adjustment facilities.
2. System to follow high-rate activated sludge system.
3. Detention time = 3 hours.
4. O_2 requirements: 1.5 lbs O_2/lb BOD_5 removed plus 4.6 lbs O_2/lb NH_3-N oxidized.
5. Sludge return pumps sized for 100 percent recycle. Operated at 50 percent recycle.
6. Final clarifier overflow rate = 600 gpd/sq ft.
7. Process performance:

Wastewater Characteristics

	In	Out*
BOD_5, mg/l	40	10
COD, mg/l	80	35
TSS, mg/l	35	20
Total-P, mg/l	9	8
NH_3-N, mg/l	19	1
NO_3-N, mg/l	0	18

*Following clarification.

References: 2, 7

FIGURE H-45 SEPARATE NITRIFICATION (WITH CLARIFIER)

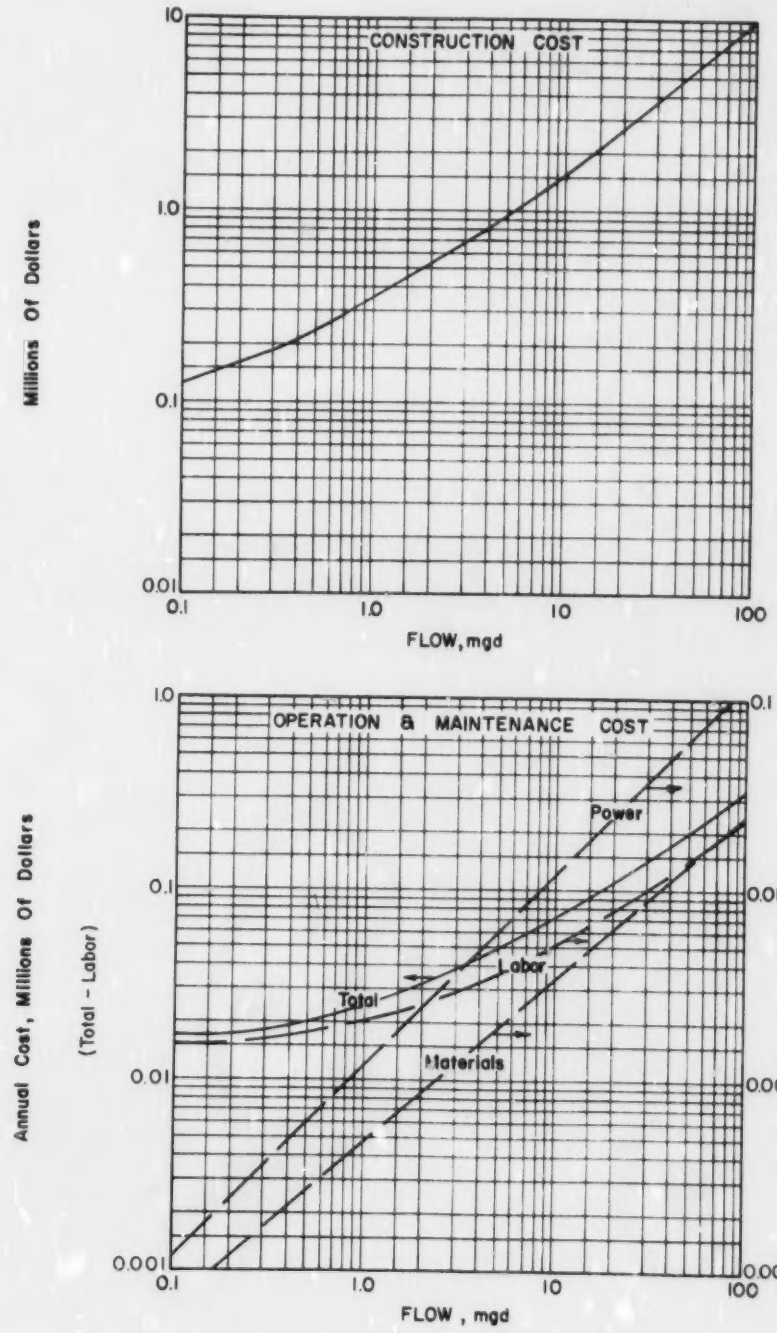


FIGURE H-46

SEPARATE DENITRIFICATION (WITH CLARIFIER)

Service Life: 40 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include denitrification tanks (uncovered), mixers, methanol feed, clarifiers, sludge recycle and waste pumps, but do not include reaeration facility. (See Figure H-61.)
2. Two hours detention time in denitrification tank.
3. MLVSS = 2,000 mg/1.
4. Denitrification recycle pumps sized for 100 percent recycle, operated at 50 percent recycle.
5. Final clarifier overflow rate = 600 gpd/sq ft.
6. 3 lbs methanol per lb of nitrate nitrogen removed.
7. Methanol storage - 30 days supply with a minimum tank size of 500 gallons.
8. Process performance:

Wastewater Characteristics

	In	Out
BOD_5, mg/1	10	10
COD, mg/1	35	45
TSS, mg/1	20	20
Total-P, mg/1	8	8
NH_3-N, mg/1	1	1
NO_3-N, mg/1	19	1

References: 2, 19

FIGURE H-46 SEPARATE DENITRIFICATION (WITH CLARIFIER)

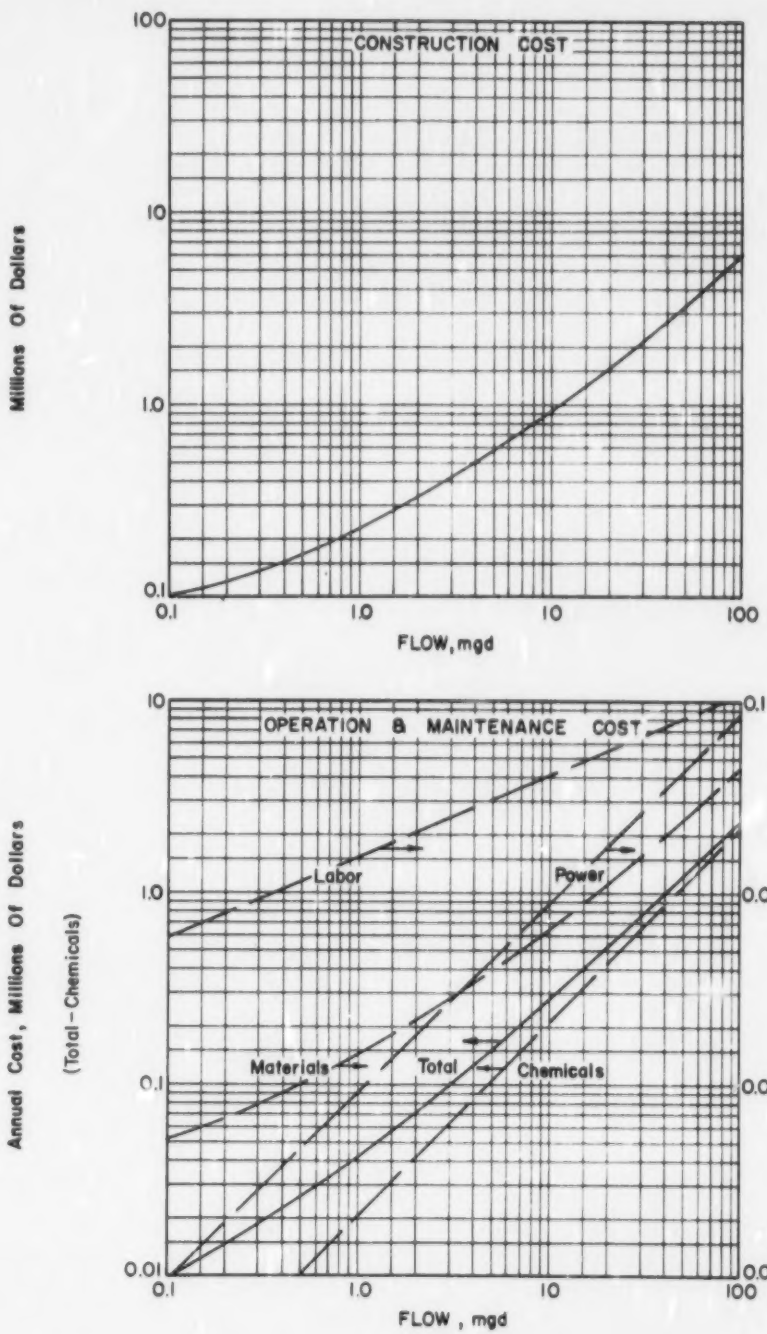


FIGURE H-47

BREAKPOINT CHLORINATION

Service Life: 15 years

Relative Reliability: Level B

Design Basis:

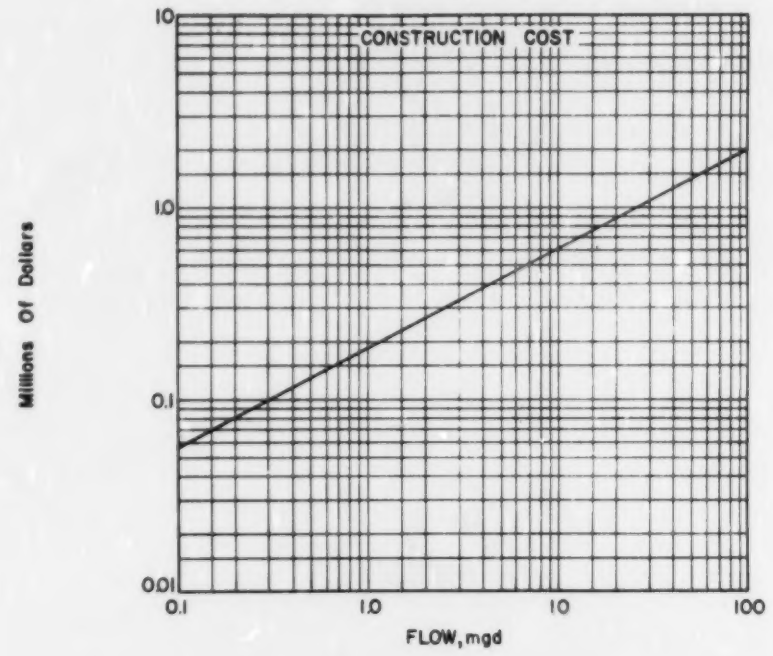
1. Construction costs include:
   a. Chlorine storage and feed system.
   b. Lime storage and feed system (1 hp/800 gal mixing).
   c. Chlorine contact tank (30 minutes detention).
   d. Costs do not include a dechlorination facility, but this should generally be included whenever breakpoint chlorination is used. (See Figure H-59.)
2. Chemical costs based on 10 lbs Cl_2/lb NH_3-N in feed (1,500 lbs/mg) and 9 lbs CaO/lb Cl_2 (1,350 lbs/mg).
3. Process performance:

Wastewater Characteristics

	In	Out
NH_3-N, mg/l	18	2

References: 4, 5, 7, 19

FIGURE H-47 BREAKPOINT CHLORINATION



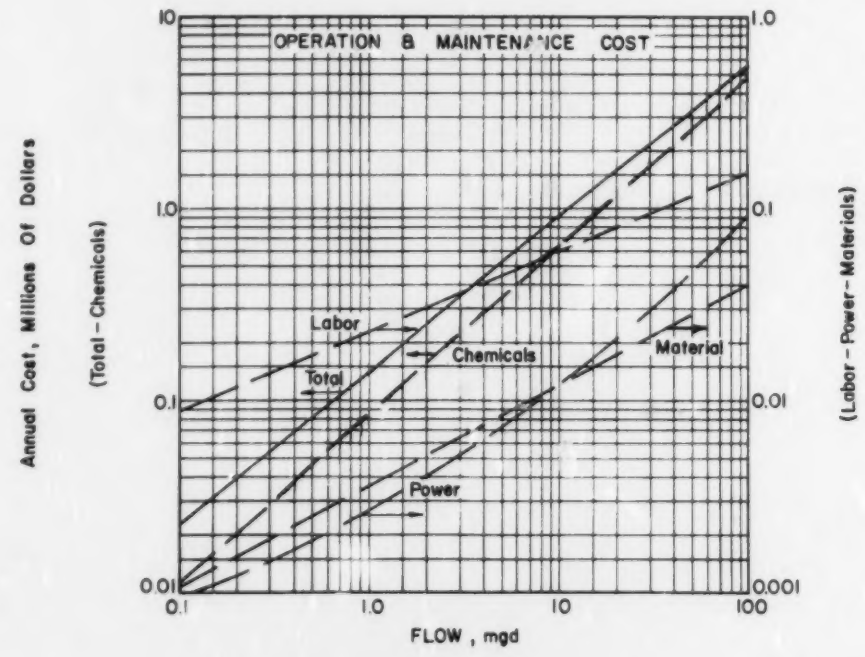


FIGURE H-48

AMMONIA STRIPPING

Service Life: 30 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include:

   a. Ammonia stripping tower - 20' high packed with 1/2 inch diameter schedule 80 PVC pipe at 3 inch centers horizontally with alternate layers placed at right angles at 2 inch centers vertically.

   b. Pumps - 50 ft TDH.

   c. Lime feed facilities to raise pH to 11-11.5 and sulfuric acid facilities to subsequently neutralize the treated effluent.

2. Hydraulic loading: 1.0 gpm/sq ft.

3. Air/water ratio: 400 cu ft/gal.

4. Process performance:

Wastewater Characteristics

	In	Out
NH_3, mg/l	18	3

References: 5, 11, 19, 26

FIGURE H-48 AMMONIA STRIPPING

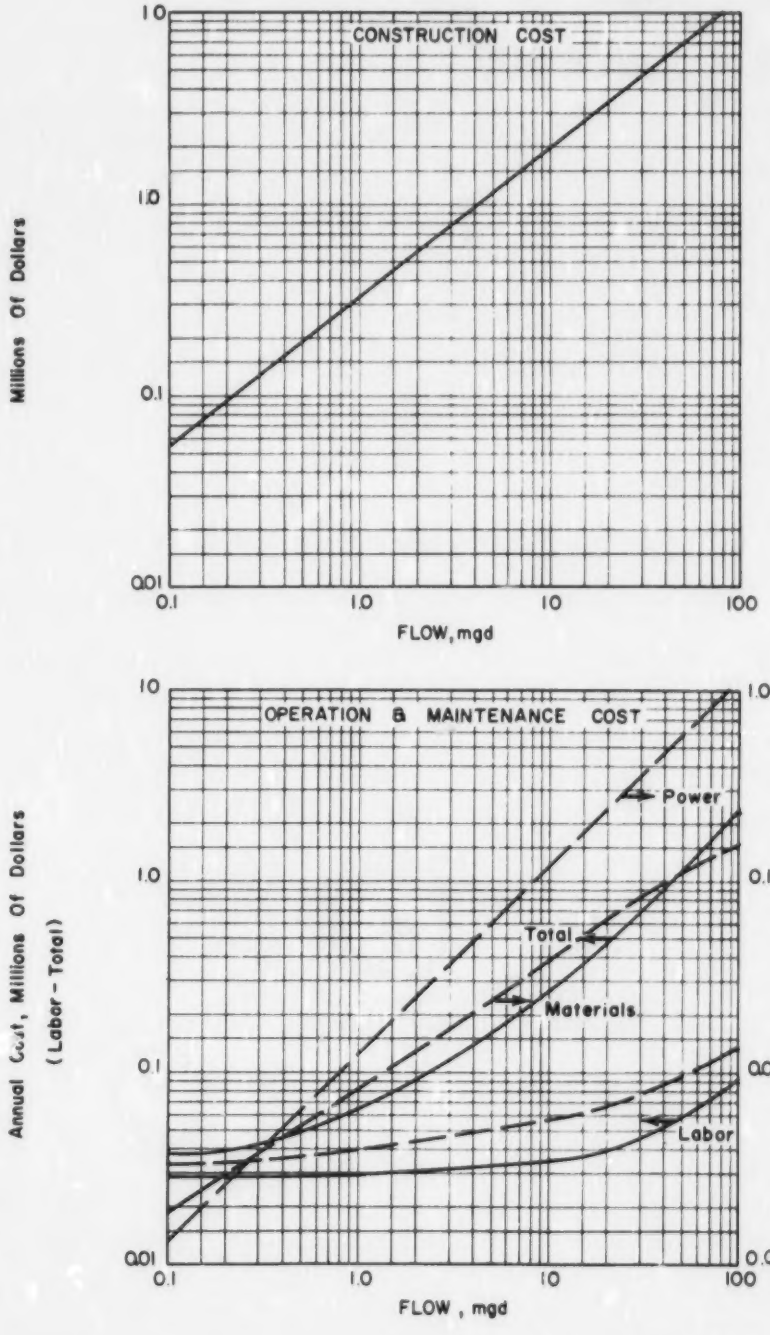


FIGURE H-49

ION EXCHANGE (FOR AMMONIA REMOVAL)

Service Life: 30 years

Relative Reliability: Level B

Design Basis:

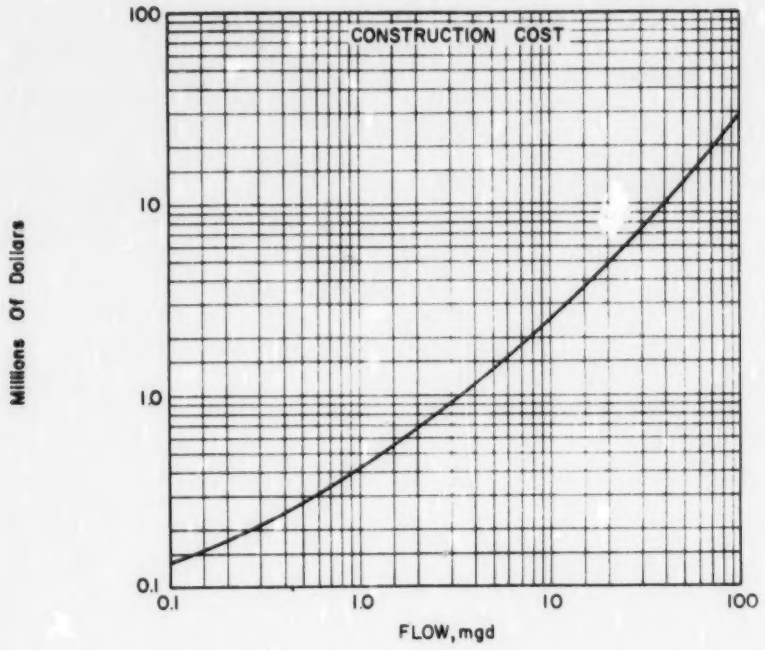
1. Construction costs include:
   a. Gravity feed clinoptilolite beds with loading rate of 5.25 gpm/sq ft at 4 ft depth.
   b. Blackwash regeneration facilities at 8 gpm/sq ft.
   c. Influent pumping at 15 ft TDH.
   d. Sodium chloride regeneration facilities using 2 percent NaCl solution, 40 bed volumes/regeneration, and 1 regeneration/24 hours.
   e. Closed-loop air stripping tower for regenerant recovery.
   f. Clarification - softening facility for spent regenerant.
2. Chemical costs include: makeup clinoptilolite and makeup regenerant.
3. Ammonia sulfate produced by this system may be sold to defer O & M costs; however, it was not included in this cost estimate.
4. Process performance:

Wastewater Characteristics

	In	Out
NH_3-N, mg/l	18	1

References: 19, 49

FIGURE H-49 ION EXCHANGE (FOR AMMONIA REMOVAL)



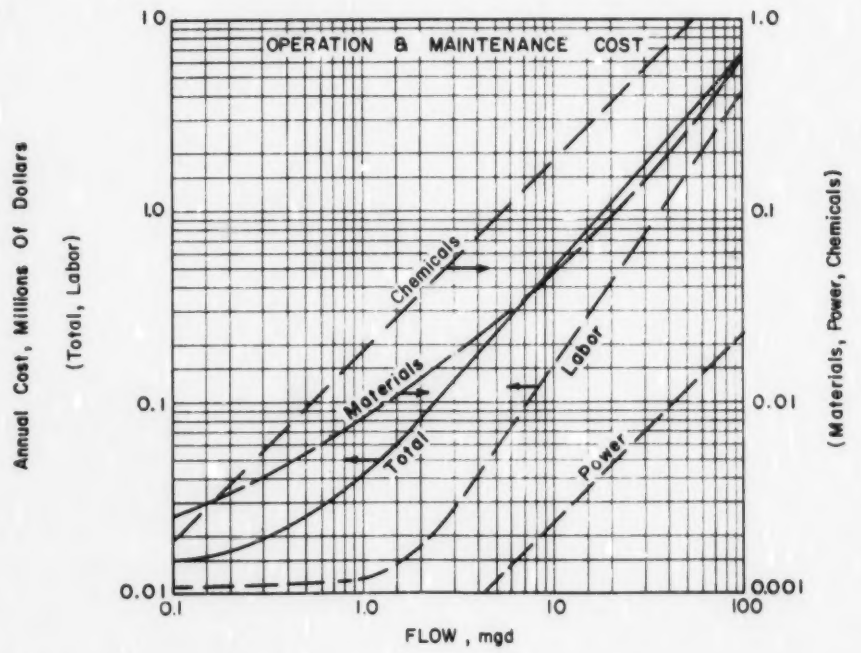


FIGURE H-50

PHOSTRIP

Service Life: 40 years

Relative Reliability: Level B

Design Basis:

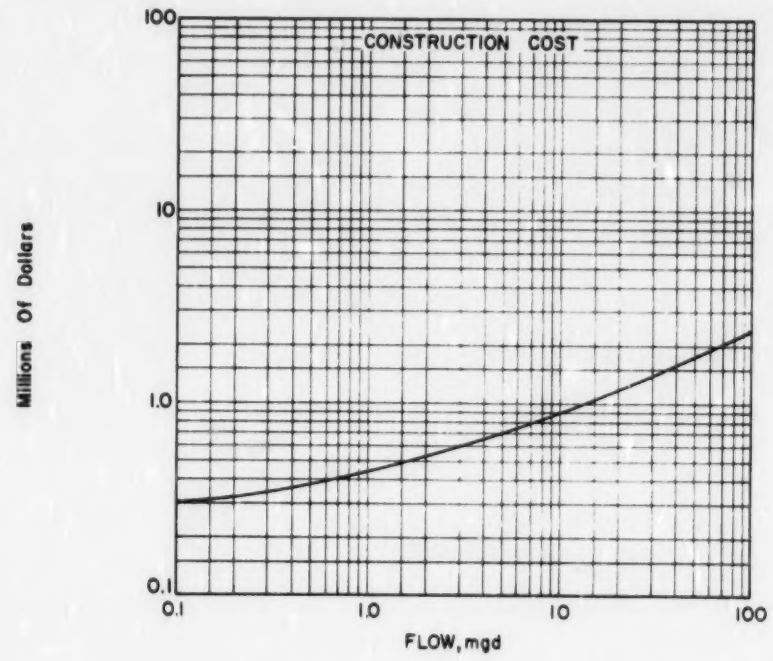
1. Construction costs include:
   a. Stripper (10 hours detention at 50 percent of return sludge).
   b. Flash mixer.
   c. Flocculator - clarifier.
   d. Thickeners.
   e. Lime feed and storage facilities.
2. Lime cost based on 225 lbs/mg.
3. Process applies only to activated sludge.
4. Process performance:

Wastewater Characteristics

	In	Out
Total-P, mg/l	9	2

Reference: 20

FIGURE H-50 PHOSTRIP



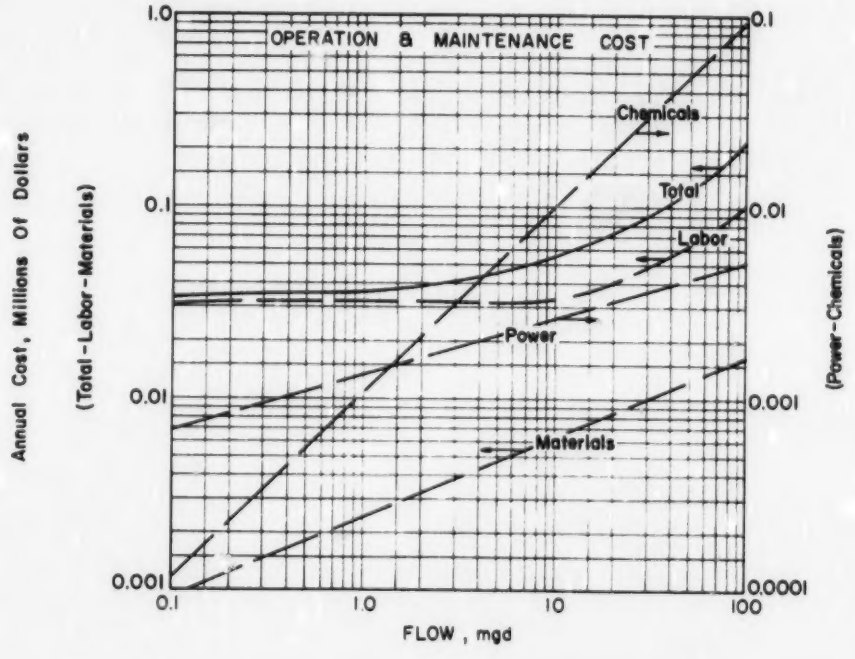


FIGURE H-51

POLYMER FEED SYSTEM

Service Life: 20 years

Relative Reliability: Level B

Design Basis:

1. System includes chemical storage, chemical feeding, rapid mix; flocculation and settling are included in a separate curve. The system is not for sludge conditioning.

2. Polymer dosage at 1 mg/l (8.34 lbs/mg).

3. Construction costs include:

   a. Use of dry polymer.

   b. Feedstock solution - 0.25 percent.

   c. Piping and building to house the feeding equipment and to store bags are included.

   d. Systems for 1 mgd plant size and smaller, use manual procedures. Two systems of tanks and feeders are included.

   e. For the 10 mgd plant size, the cost includes two feeders and mixing tanks, one day tank, and two solution feeders.

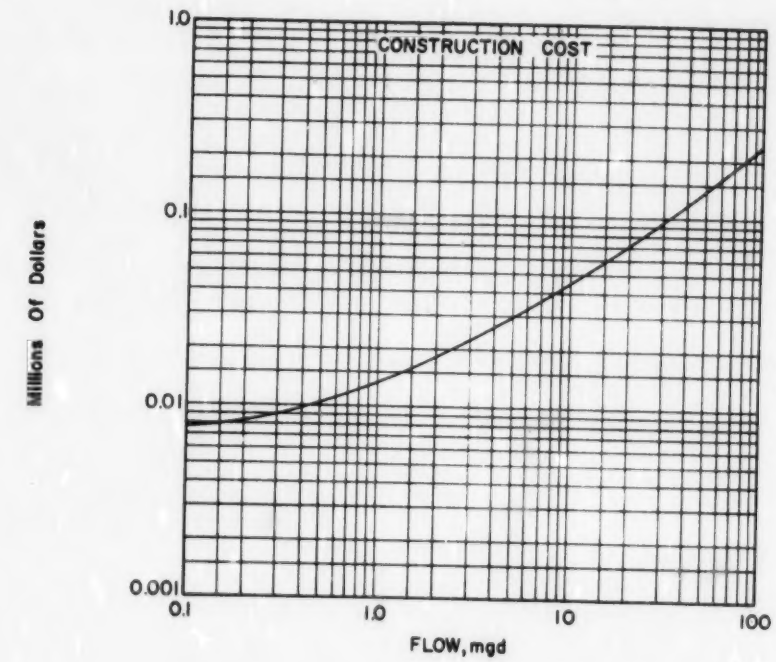
   f. For the 100 mgd plant size, the cost includes four feeders and mixing tanks, two holding tanks, and ten solution feeders.

   g. The rapid-mix tank is concrete, and is equipped with stainless steel mixer and handrails.

   h. For the 0.1 mgd plant size, no separate building is required. Cost includes manual operation with feeder, mix tank, solution feeder, and holding tank.

References: 6, 9, 18, 25

FIGURE H-51 POLYMER FEED SYSTEM



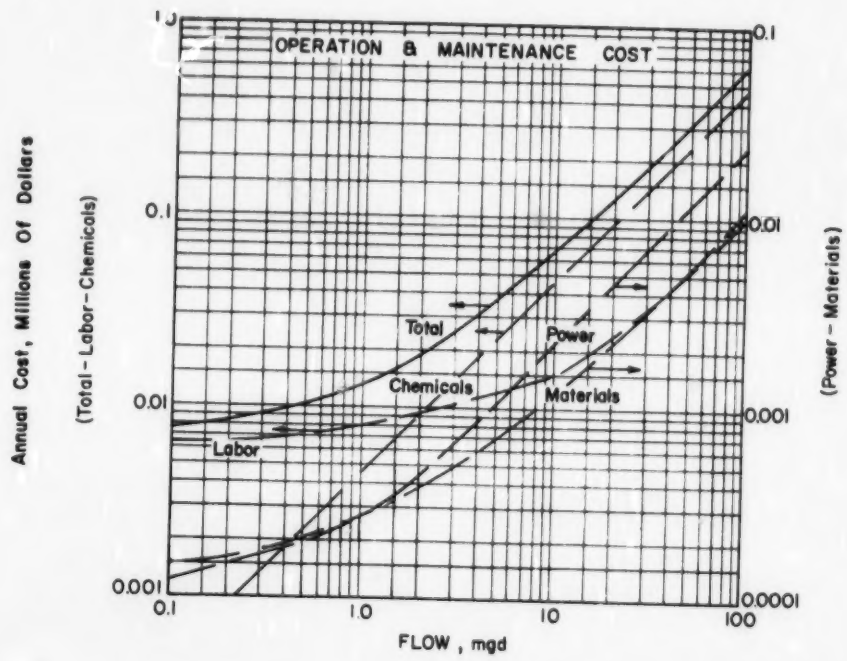


FIGURE H-52

MINERAL ADDITION

Service Life: 20 years

Relative Reliability: Level B

Design Basis:

1. Alum dosage of 200 mg/l and ferric chloride dosage of 100 mg/l. Phosphorus removal - for other dosages see adjustments below.

2. The rapid-mix tank is constructed of concrete, and multiple basins are used for volumes greater than 1,500 cubic feet.

3. Costs include:

   a. Liquid chemicals (8.3 percent Al_2O_3 and 35 percent $FeCl_3$).

   b. Chemical feed equipment sized for twice the average feed rate.

   c. Storage of at least 15 days.

   d. Price of building is included except for plants with a capacity of less than 1 mgd.

   e. Rapid-mix tank includes stainless steel mixer.

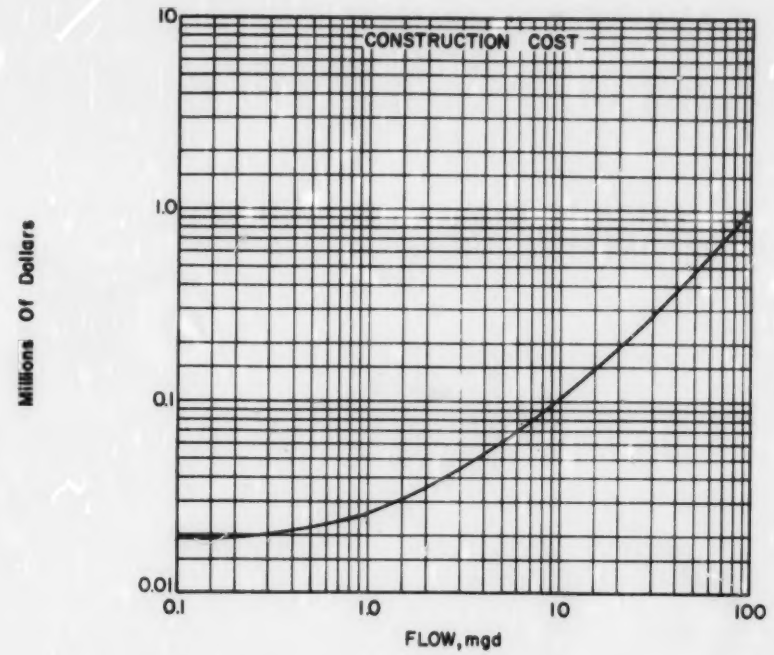
Adjustment Factor:

To adjust costs enter curve at effective flow (Q_E)

Alum: $$Q_E = Q_{DESIGN} \times \frac{\text{Alum Dose}}{200 \text{ mg/l}}$$

$FeCl_3$ = $$Q_E = Q_{DESIGN} \times \frac{FeCl_3 \text{ Dose}}{100 \text{ mg/l}}$$

FIGURE H-52[1] MINERAL ADDITION (ALUM)



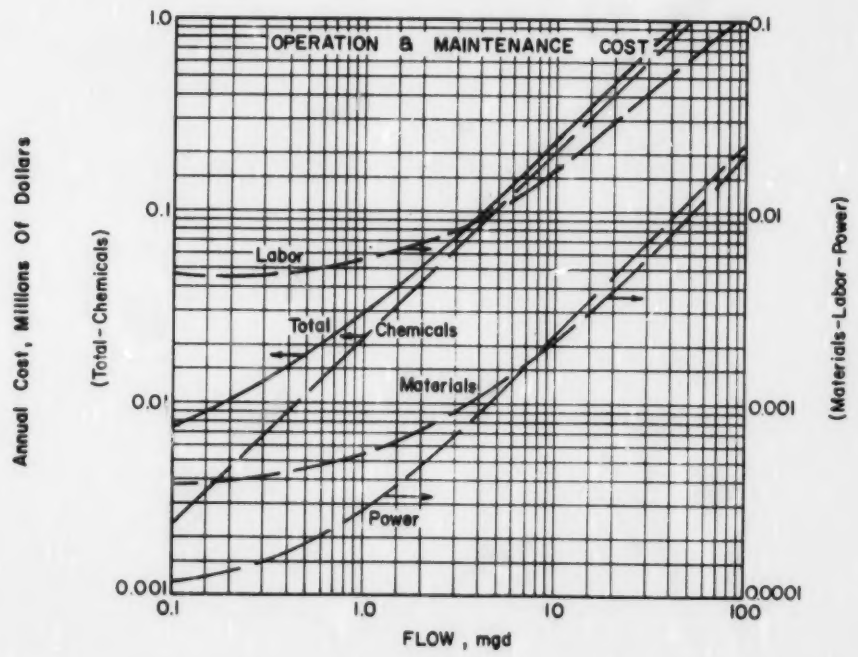


FIGURE H-52

MINERAL ADDITION

Service Life: 20 years

Relative Reliability: Level B

Design Basis:

1. Alum dosage of 200 mg/l and ferric chloride dosage of 100 mg/l. Phosphorus removal - for other dosages see adjustments below.
2. The rapid-mix tank is constructed of concrete, and multiple basins are used for volumes greater than 1,500 cubic feet.
3. Costs include:
   a. Liquid chemicals (8.3 percent Al_2O_3 and 35 percent $FeCl_3$).
   b. Chemical feed equipment sized for twice the average feed rate.
   c. Storage of at least 15 days.
   d. Price of building is included except for plants with a capacity of less than 1 mgd.
   e. Rapid-mix tank includes stainless steel mixer.

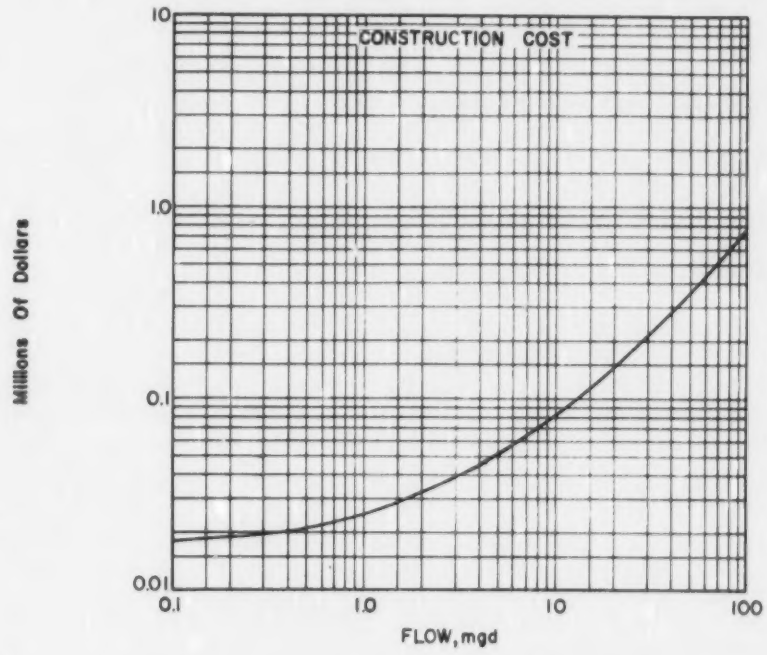
Adjustment Factor:

To adjust costs enter curve at effective flow (Q_E)

Alum: $Q_E = Q_{DESIGN} \times \frac{\text{Alum Dose}}{200 \text{ mg/l}}$

$FeCl_3 = Q_E = Q_{DESIGN} \times \frac{FeCl_3 \text{ Dose}}{100 \text{ mg/l}}$

FIGURE H-52[2] MINERAL ADDITION (FERRIC CHLORIDE)



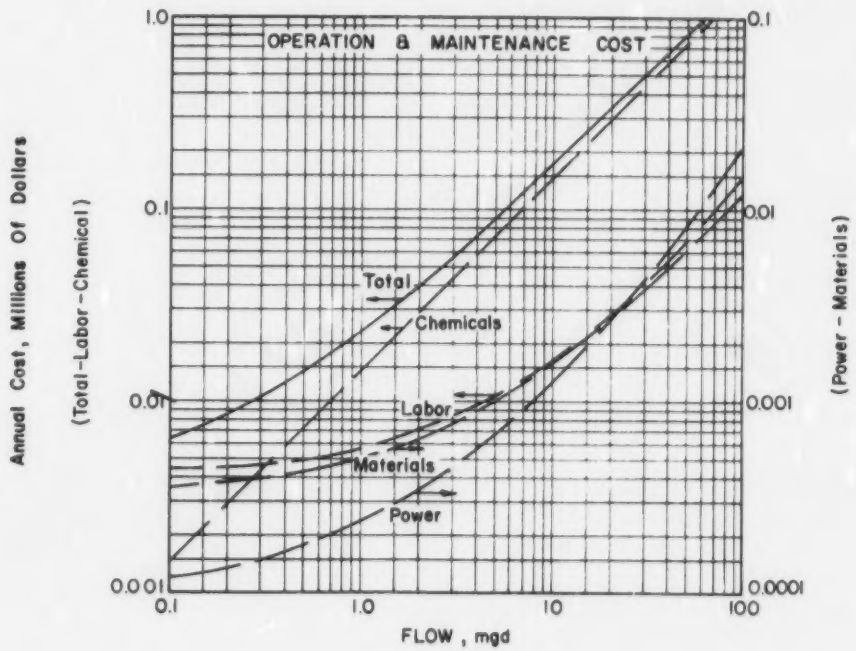


FIGURE H-53

TWO-STAGE TERTIARY LIME TREATMENT
(WITHOUT RECALCINATION)

Service Life: 40 years

Relative Reliability: Level B

Design Basis:

1. Typical secondary effluent as feed to two-stage lime treatment.
2. Lime dosage rate = 400 mg/l or 3,340 lb/mg as CaO.
3. Clarifier overflow rate = 1,000 gpd/sq ft.
4. Construction cost includes: lime storage and feed facilities, rapid-mix facilities, flocculator/clarifiers, flow and pH controls, and recarbonization facilities.
5. Costs do not include recalcination facilities (see Figure H-54).
6. Process performance:

Wastewater Characteristics

	In	Out
BOD_5, mg/l	20	8
COD, mg/l	45	18
TSS, mg/l	20	20
Total-P, mg/l	8	0.5 (with filtration) 1.5 (without filtration)

Adjustment Factor:

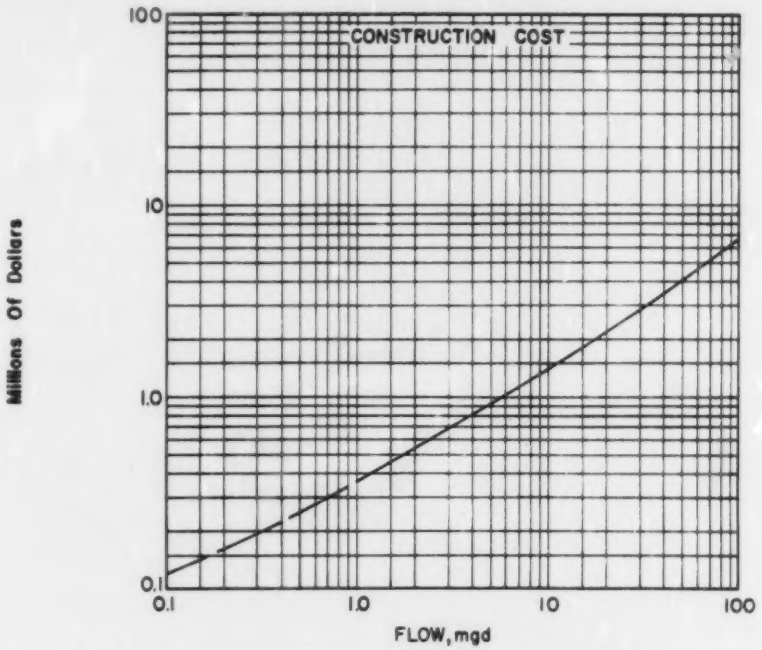
To adjust costs, enter curves at effective flow (Q_E)

Construction Cost: $Q_E = Q_{DESIGN} \times \frac{1000}{\text{New Design Overflow Rate}}$

Chemical Costs (O&M): $Q_E = Q_{DESIGN} \times \frac{\text{New Lime Dosage}}{400}$

References: 4, 5, 7, 8, 11, 18, 26, 31

FIGURE H-53 TWO STAGE TERTIARY LIME TREATMENT
(WITHOUT RECALCINATION)



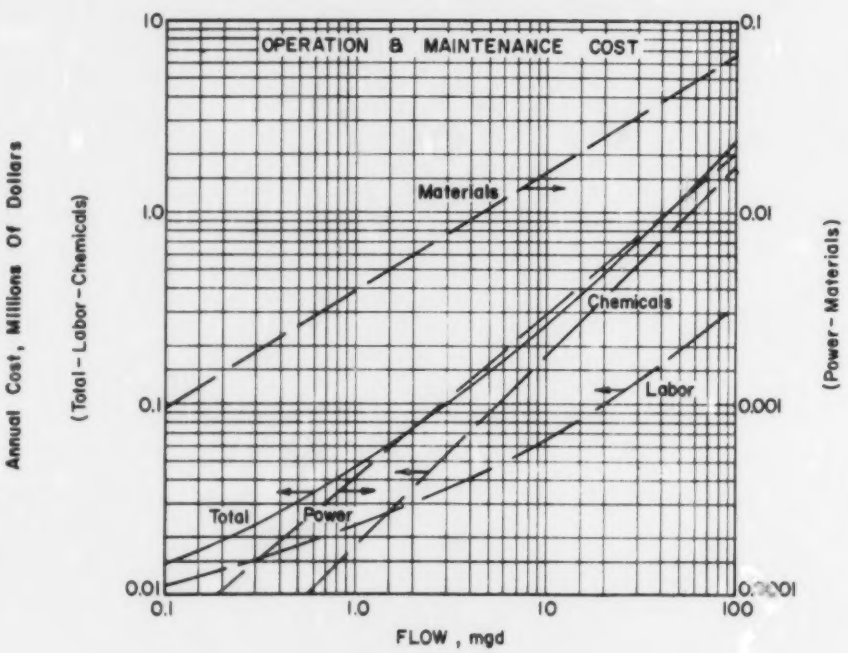


FIGURE H-54

LIME RECALCINATION

Service Life: 30 years

Relative Reliability: Level B

Design Basis:

1. Quantity of lime sludge: 4,500 lb/mg; 30 percent solids (from two-stage tertiary lime treatment).

2. Operations:

Flow	Wet Solids lbs/hr (24 hrs/day)	Days/Week Operating	Hours/Day Operating	Furnace Loading lb/hr	Hearth Area sq ft
0.1	62.5	1	20	525	112
1.0	625	6	16	1,095	256
10.0	6,250	7	20	7,500	2 at 760
100.0	62,500	7	20	75,000	3 at 5,070

3. Fuel requirements (No. 2 fuel oil): 129,000 gal/yr/mgd.

4. Construction costs included: recalcination furnace, sludge conveyors, storage, hoppers, building.

Adjustment Factor:

When lime recalcination is used, reduce the chemical cost of two-stage tertiary lime treatment (Figure H-53) by 70 percent.

References: 4, 7, 8, 11, 18

FIGURE H-54 LIME RECALCINATION

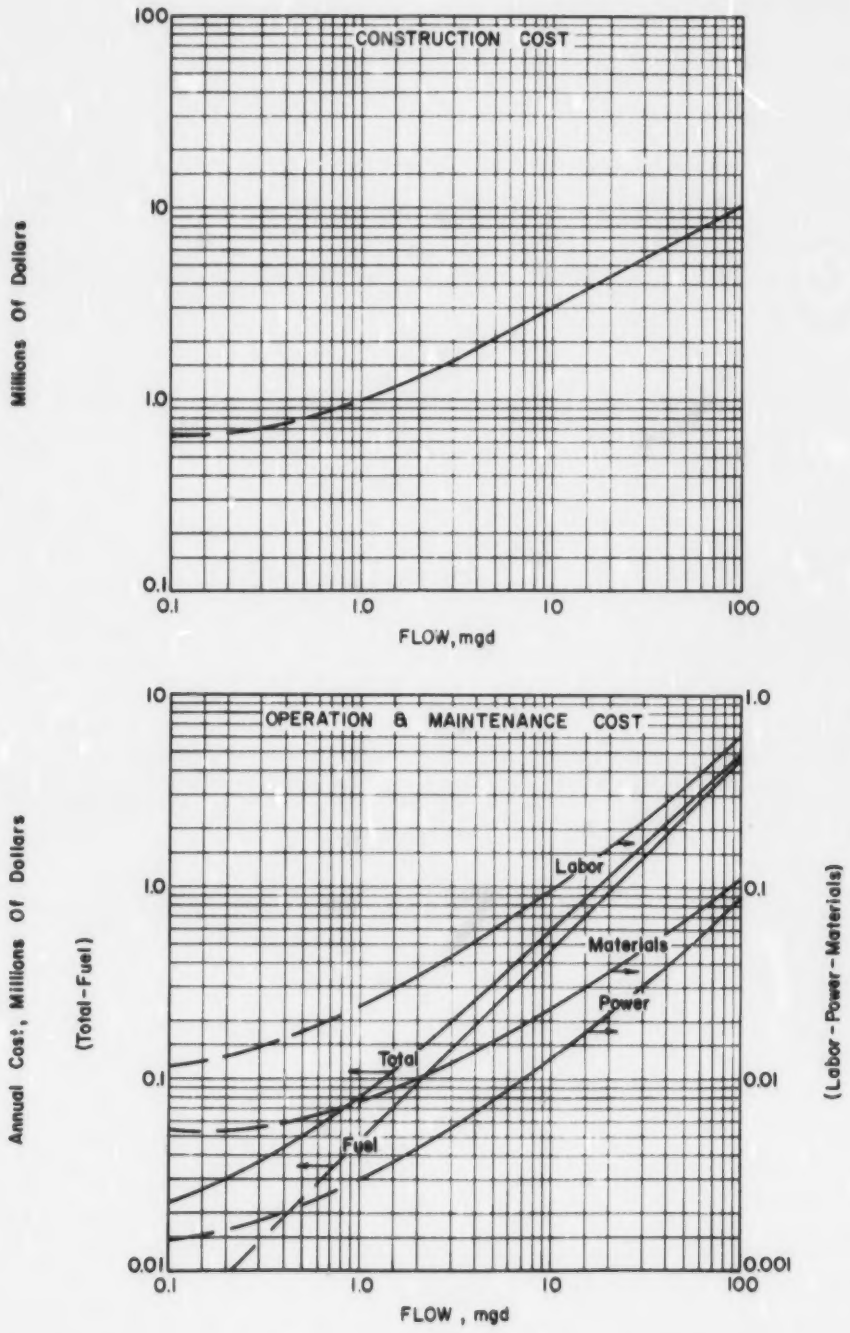


FIGURE H-55

MICROSCREENING

Service Life: 20 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include: tanks, drums, screens, backwash equipment, drive motors, and building. Instrumentation for automatic operation is included.
2. Hydraulic loading = 2.5 gpm/sq ft at average flow.
3. Screen mesh: 25 microns.
4. Peripheral drum speed: 15 fpm at 3-in. head loss.
5. Backwash 3 percent of throughput at 25 psi.
6. Process performance:

Wastewater Characteristics

	In	Out
TSS, mg/l	20	12

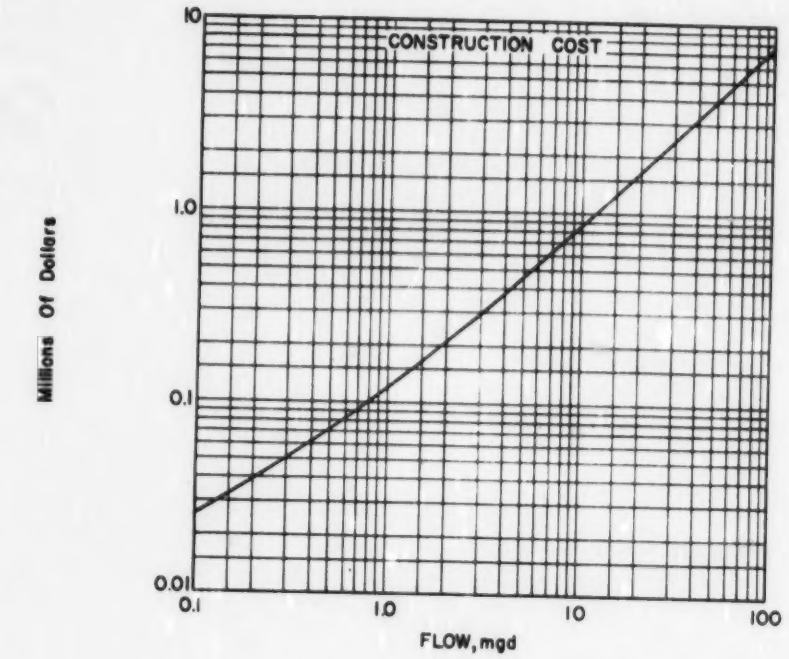
Adjustment Factor:

To determine costs for hydraulic loadings different than that above, enter curve at effective flow (Q_E)

$$Q_E = Q_{DESIGN} \times \frac{2.5 \text{ gpm/sq ft}}{\text{New Design Hydraulic Loading}}$$

References: 5, 8, 11, 24, 26

FIGURE H-55 MICROSCREENING



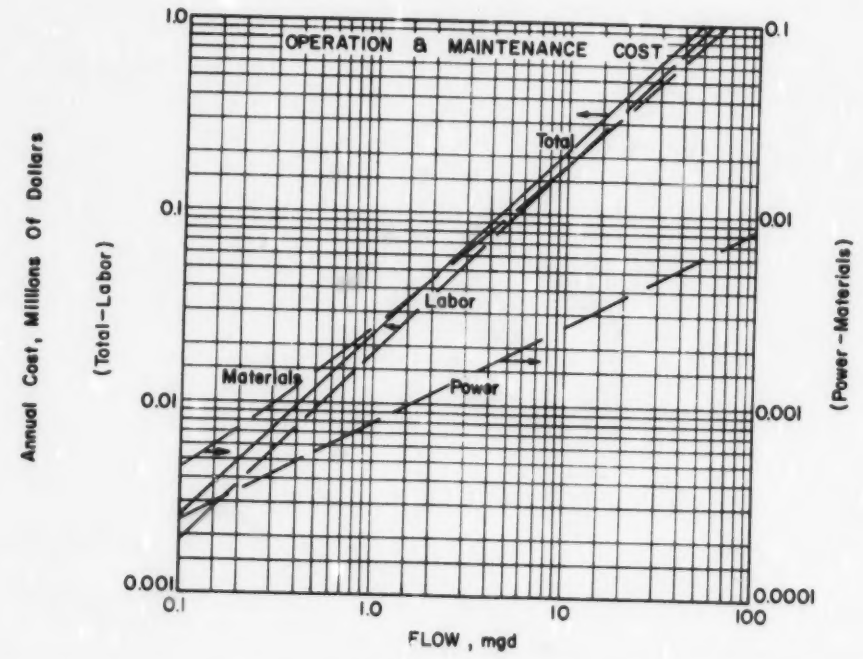


FIGURE H-56

GRAVITY FILTRATION (DUAL-MEDIA)

Service Life: 30 years

Relative Reliability: Level B

Design Basis:

1. Feed rate = 4 gpm/sq ft at average flow.
2. Backwash rate = 15 gpm/sq ft with air scour.
3. Backwash holding tank = capacity of 2 backwash cycles.
4. Construction costs include facilities for backwash storage, all feed and backwash pumps, piping, and building.
5. Process performance:

Wastewater Characteristics

	In	Out
BOD_5, mg/l	20	15
COD, mg/l	40	30
TSS, mg/l	20	5
Total-P, mg/l	2	1

Adjustment Factor:

To adjust for loading rates other than above, enter curve at effective flow (Q_E).

$$Q_E = Q_{DESIGN} \times \frac{4 \text{ gpm/sq ft}}{\text{New Design Filtration Rate}}$$

References: 4, 7, 24

FIGURE H-56 GRAVITY FILTRATION (DUAL-MEDIA)

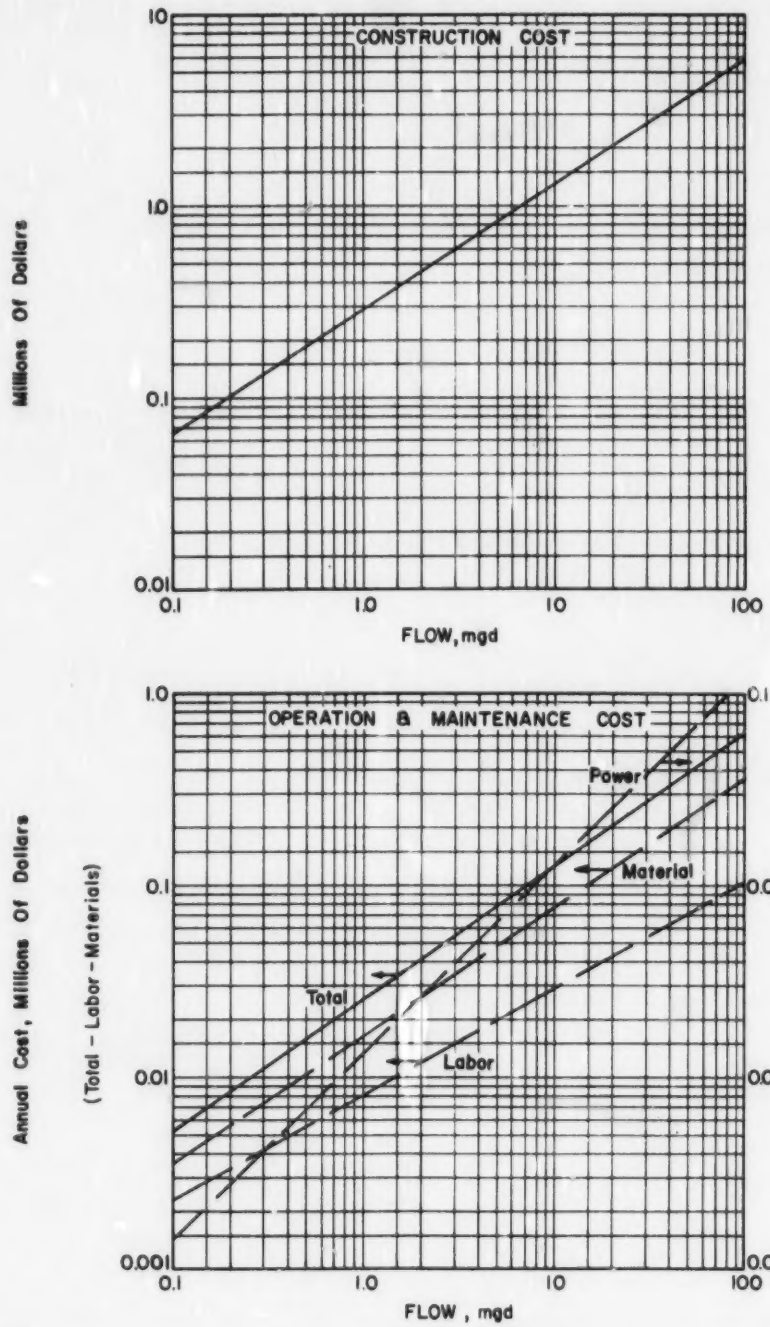


FIGURE H-57

ACTIVATED CARBON ADSORPTION

Service Life: 35 years

Relative Reliability: Level B

Design Basis:

1. Contact time = 30 minutes (empty bed basin).
2. Regeneration furnace loading = 80 lb/sq ft/day.
3. Construction costs include:
   a. For flows above breakpoint:
      1. Carbon columns (minimum of 3).
      2. Virgin & spent carbon storage tanks.
      3. Feed and backwash pumps and all necessary piping.
      4. Operations building.
      5. Regeneration furnace (Multiple Hearth Furnace).
      6. Slurry tank and steam generator.
   b. For flow below breakpoint:
      1. Items a.1-a.4 - no regeneration.
4. Carbon Dosage

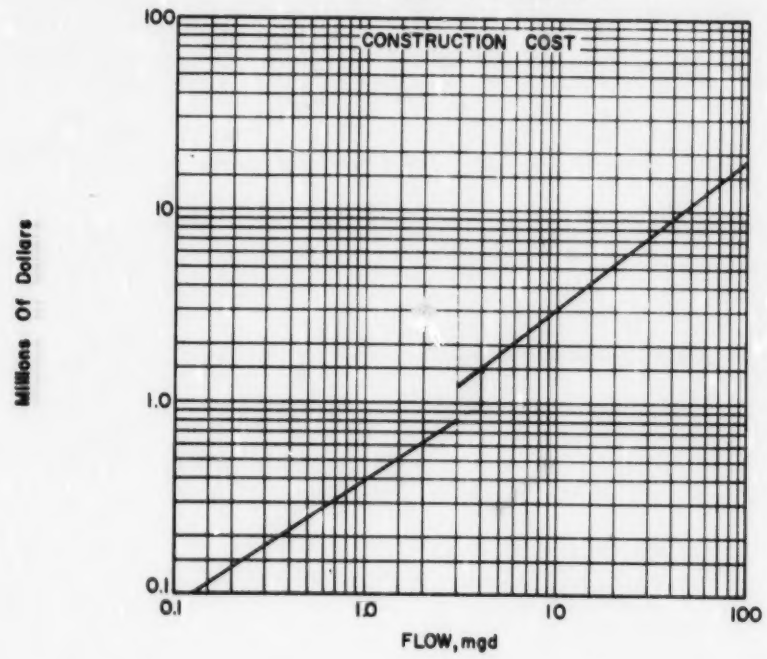
   H-57[1] - Tertiary Effluent: for flow less than 3.0 mgd = 30 lb/mg (without regeneration); for flow greater than 3.0 mgd = 3 lb/mg (10 percent make up) (with regeneration)

   H-57[2] - Physical/Chemical: for flow less than 1.5 mgd = 1,650 lb/mg (without regeneration); for flow greater than 1.5 mgd = 165 lb/mg (10 percent make up) (with regeneration).
5. Regeneration heat requirement: 7,000 Btu/lb of carbon regeneration.
6. Effluent from activated sludge, two-stage lime treatment, and gravity dual-media filters as feed to carbon adsorbers.
7. Process performance:

Wastewater Characteristics	In	Out
BOD_5, mg/l	15	3
COD, mg/l	30	10
TSS, mg/l	5	5

References: 4, 5, 6, 7, 29

FIGURE H-57' ACTIVATED CARBON ADSORPTION
(TERTIARY EFFLUENT)



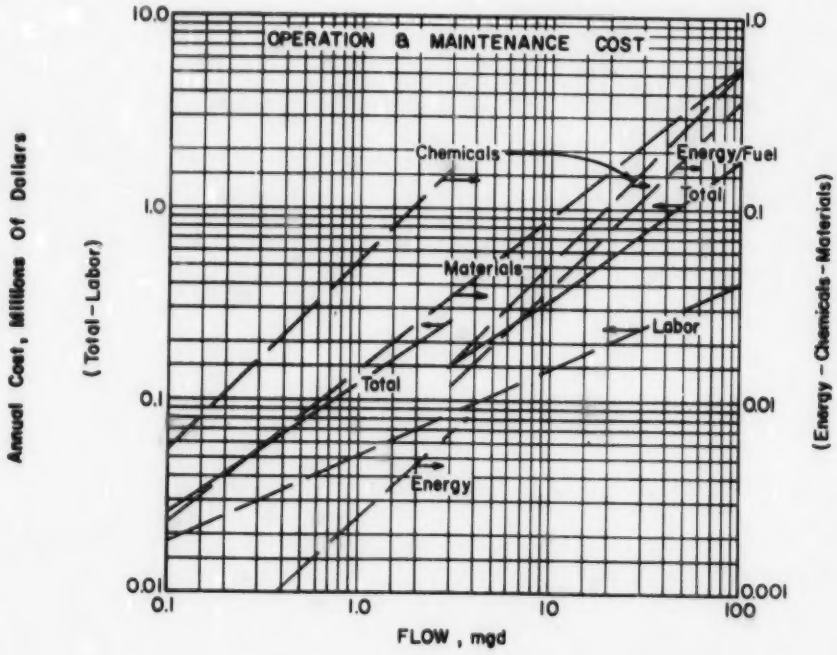


FIGURE H-57

ACTIVATED CARBON ADSORPTION

Service Life: 35 years

Relative Reliability: Level B

Design Basis:

1. Contact time = 30 minutes (empty bed basin).
2. Regeneration furnace loading = 80 lb/sq ft/day.
3. Construction costs include:
   a. For flows above breakpoint:
      1. Carbon columns (minimum of 3).
      2. Virgin & spent carbon storage tanks.
      3. Feed and backwash pumps and all necessary piping.
      4. Operations building.
      5. Regeneration furnace (Multiple Hearth Furnace).
      6. Slurry tank and steam generator.
   b. For flow below breakpoint:
      1. Items a.1-a.4 - no regeneration.
4. Carbon Dosage

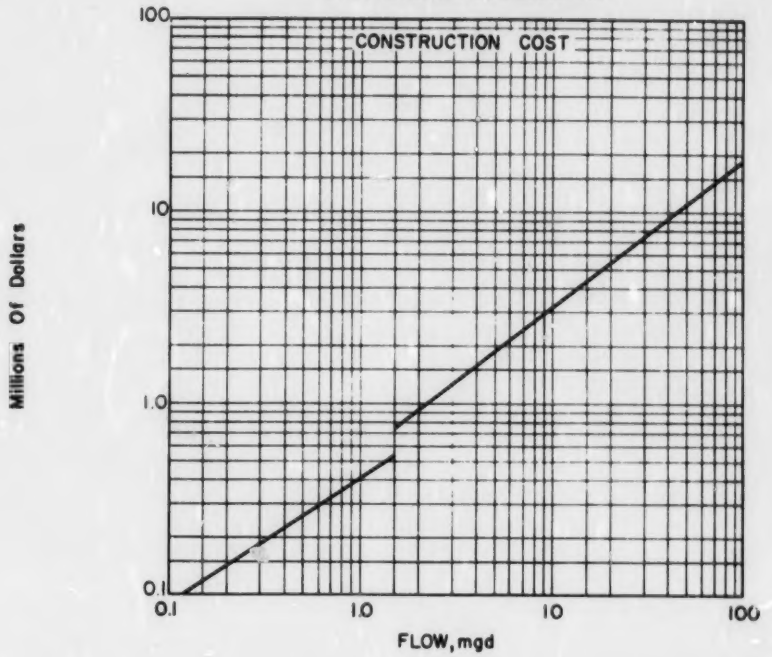
   H-57[1] - Tertiary Effluent: for flow less than 3.0 mgd = 30 lb/mg (without regeneration); for flow greater than 3.0 mgd = 3 lb/mg (10 percent make up) (with regeneration)

   H-57[2] - Physical/Chemical: for flow less than 1.5 mgd = 1,650 lb/mg (without regeneration); for flow greater than 1.5 mgd = 165 lb/mg (10 percent make up) (with regeneration).
5. Regeneration heat requirement: 7,000 Btu/lb of carbon regeneration.
6. Effluent from activated sludge, two-stage lime treatment, and gravity dual-media filters as feed to carbon adsorbers.
7. Process performance:

Wastewater Characteristics	In	Out
BOD_5, mg/l	15	3
COD, mg/l	30	10
TSS, mg/l	5	5

References: 4, 5, 6, 7, 29

FIGURE H-57[2] ACTIVATED CARBON ADSORPTION
(PHYSICAL/CHEMICAL)



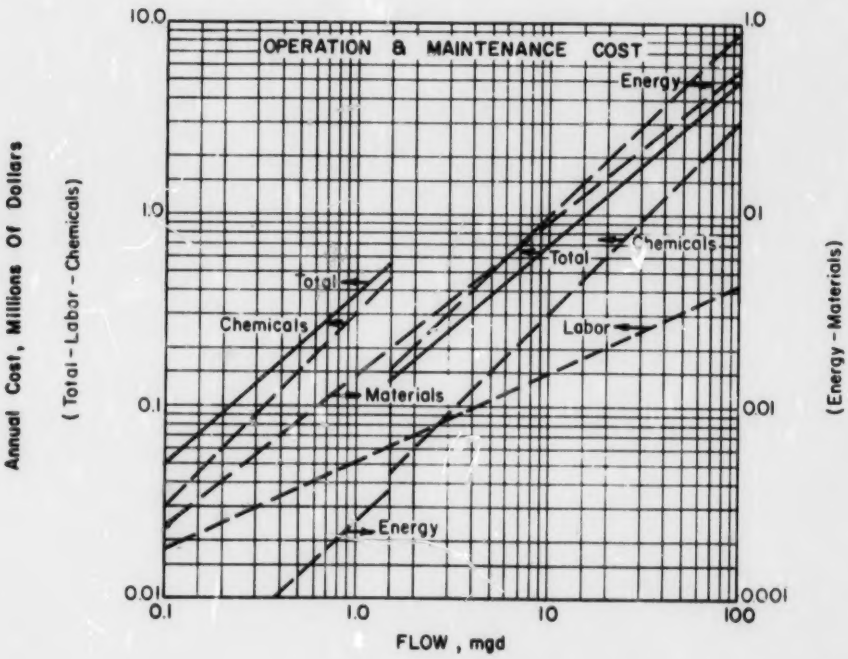


FIGURE H-58

CHLORINATION (DISINFECTION)

Service Life: 15 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include:
   a. Chlorination building.
   b. Chlorine storage and handling facilities including hoists, etc.
   c. Chlorinators.
   d. Plug flow contact chamber.
2. Average chlorine dosage, 10 mg/l.
3. Chlorination contact time, 30 min for average flow.
4. Chlorine residual, 1 mg/l.

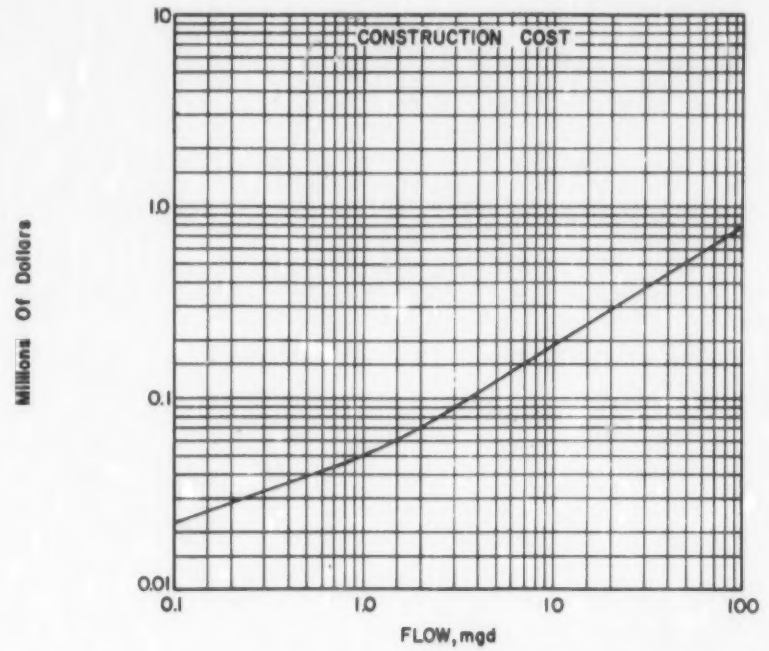
Adjustment Factor:

To adjust costs, enter curves at effective flow (Q_E)

Chemical Cost (O&M): $Q_E = Q_{DESIGN} \times \frac{\text{New Chlorine Dosage}}{10 \text{ mg/l}}$

References: 3, 7, 9

FIGURE H-58 CHLORINATION (DISINFECTION)



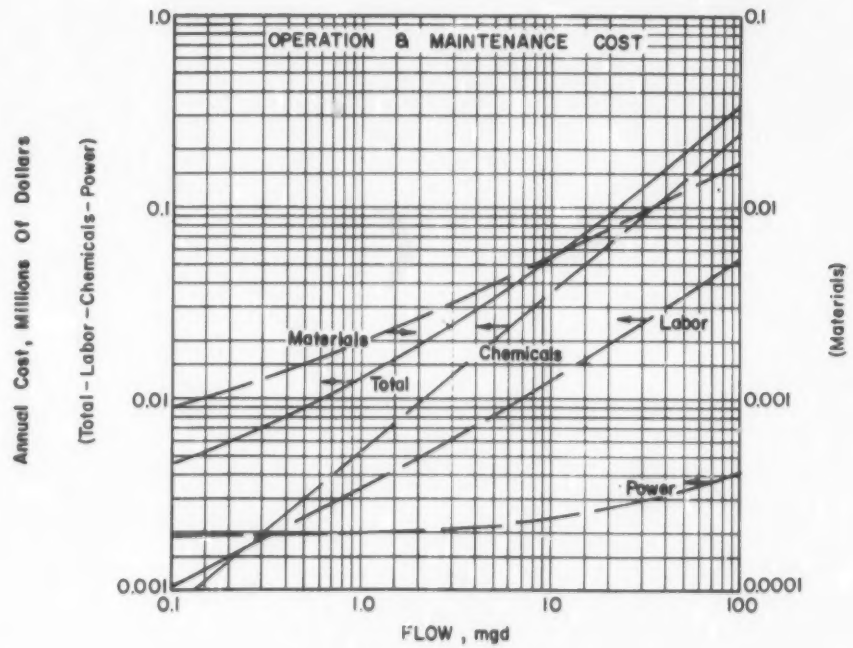


FIGURE H-59

DECHLORINATION USING SULFUR DIOXIDE

Service Life: 15 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include SO_2 feed facilities, reaction tank (1 minute detention), mixer, and storage facilities; building space not included.

2. SO_2 costs based on 20 lb/mg (1 mg/l SO_2 required per mg/l chlorine residual.

Adjustment Factor:

To adjust costs, enter curve at effective flow (Q_E)

Chemical Costs (O&M): $$Q_E = Q_{DESIGN} \times \frac{\text{New } SO_2 \text{ Dosage}}{1 \text{ mg/l } SO_2}$$

References: 1, 5

FIGURE H-59 DECHLORINATION USING SULFUR DIOXIDE

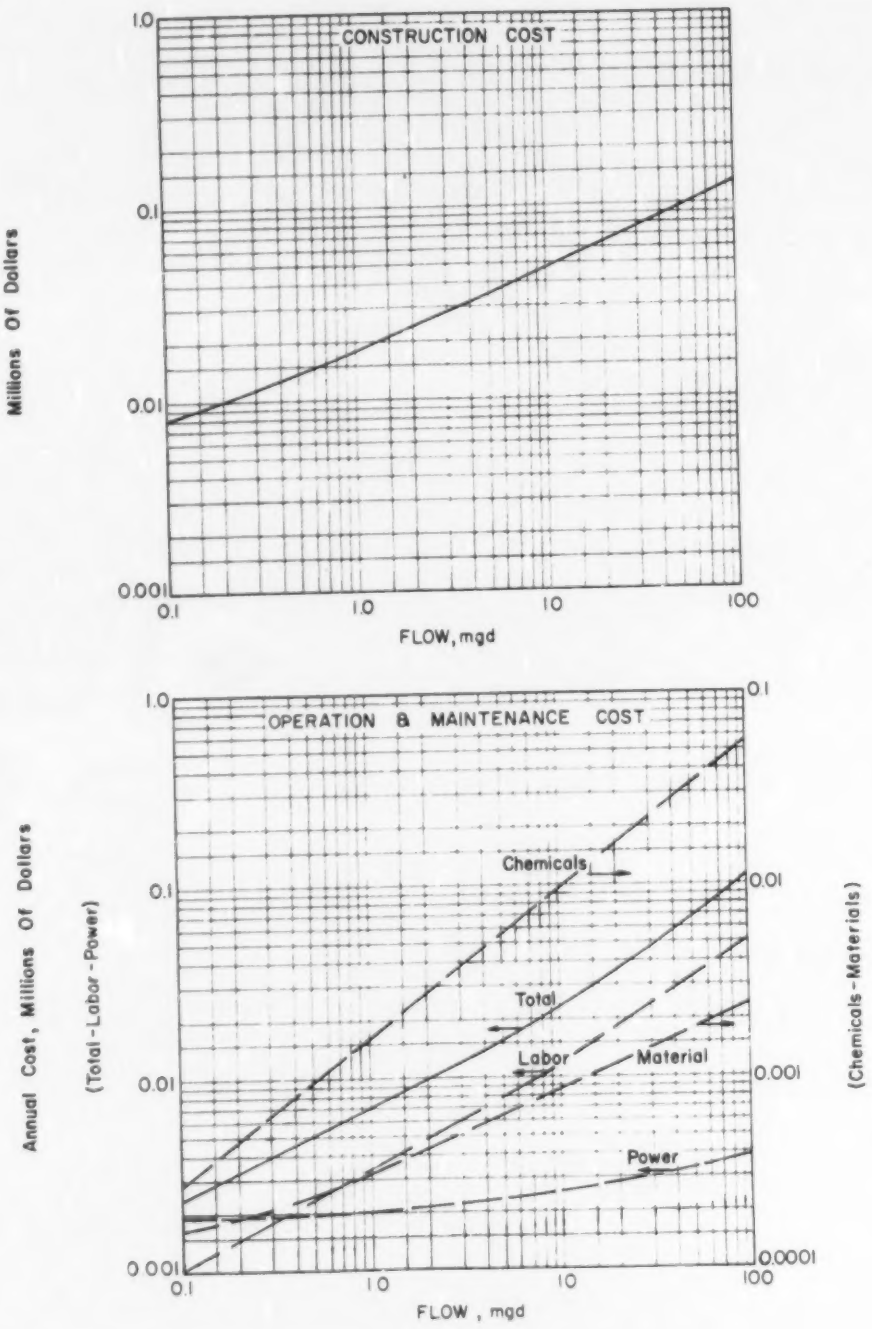


FIGURE H-60

OZONATION (AIR- AND O_2-GENERATED)

Service Life: 30 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include:

   Air Systems:

   a. Air blowers.
   b. Air filters.
   c. Air coolers.
   d. Air dryers.
   e. Ozonator.
   f. Ozone injector.
   g. Ozone-water contact chamber.
   h. Aeration chamber.

   Oxygen Systems:

   a. Oxygen storage.
   b. Ozonator.
   c. Ozone injector.
   d. Ozone-water contact chamber.
   e. Aeration chamber.

2. Oxygen requirements = 3 lb O_2/lb O_3.

3. Ozone dosage = 8 mg/l.

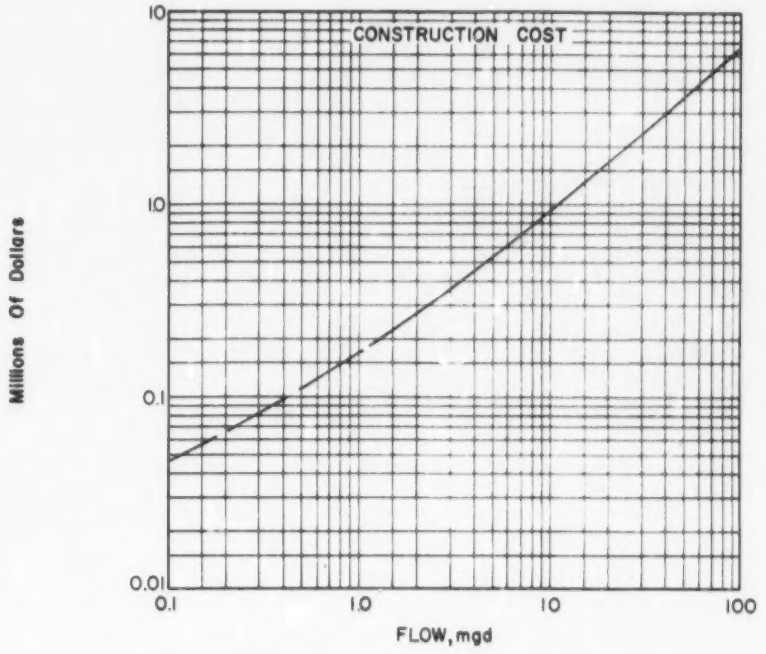
Adjustment Factor:

To adjust costs, enter curve at effective flow (Q_E)

Chemical Costs (O&M): $Q_E = Q_{DESIGN} \times \frac{\text{New Ozone Dosage}}{8 \text{ mg/l}}$

References: 1, 7

FIGURE H-60[1] OZONATION (AIR)



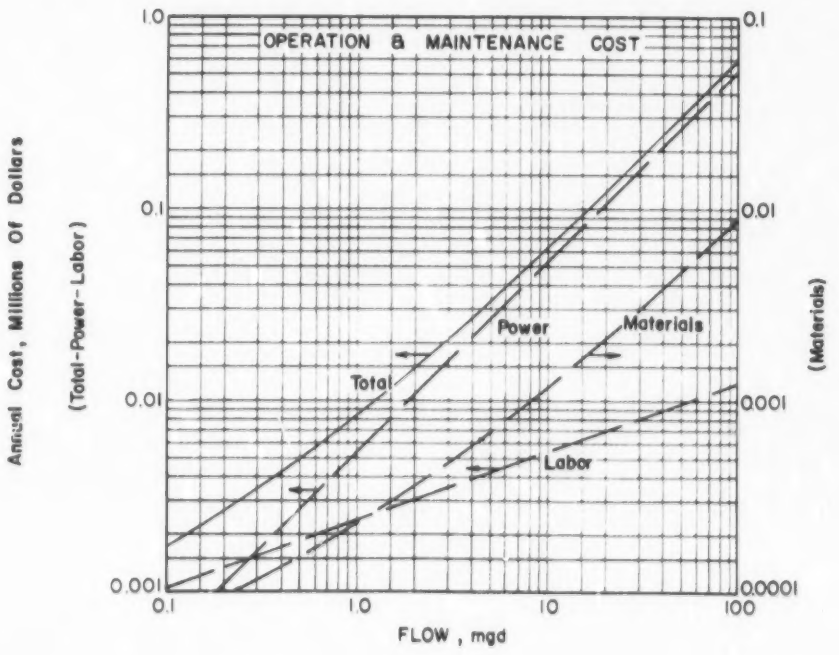


FIGURE H-60

OZONATION (AIR- AND O_2-GENERATED)

Service Life: 30 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include:

   Air Systems:

   a. Air blowers.
   b. Air filters.
   c. Air coolers.
   d. Air dryers.
   e. Ozonator.
   f. Ozone injector.
   g. Ozone-water contact chamber.
   h. Aeration chamber.

   Oxygen Systems:

   a. Oxygen storage.
   b. Ozonator.
   c. Ozone injector.
   d. Ozone-water contact chamber.
   e. Aeration chamber.

2. Oxygen requirements = 3 lb O_2/lb O_3.

3. Ozone dosage = 8 mg/l.

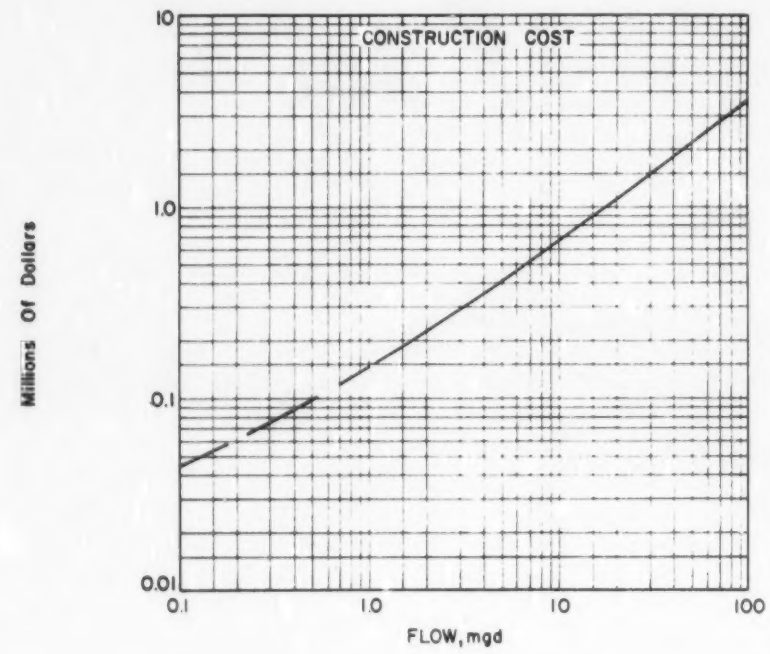
Adjustment Factor:

To adjust costs, enter curve at effective flow (Q_E)

Chemical Costs (O&M): $Q_E = Q_{DESIGN} \times \frac{\text{New Ozone Dosage}}{8 \text{ mg/l}}$

References: 1, 7

FIGURE H-60[2] OZONATION (OXYGEN)



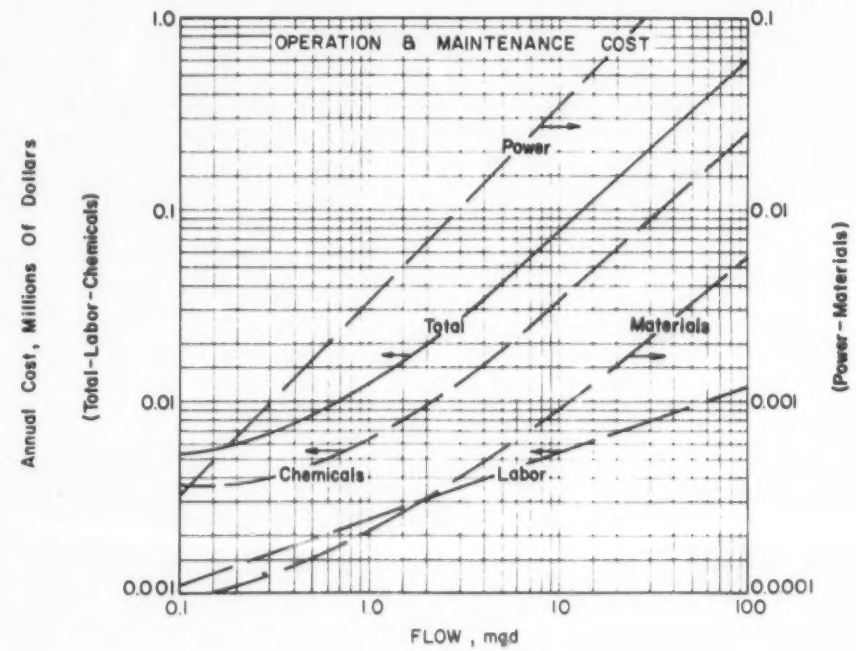


FIGURE H-61

POST AERATION

Service Life: 20 years

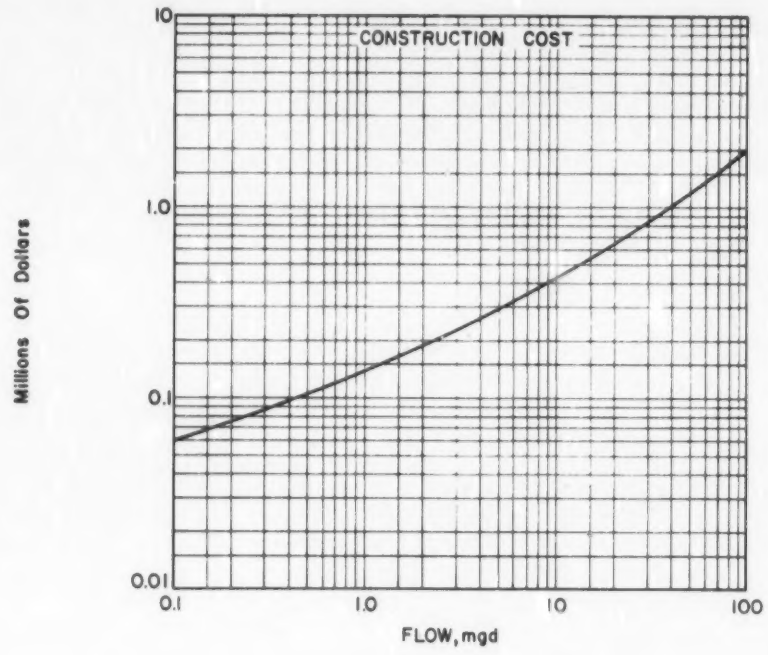
Relative Reliability: Level B

Design Basis:

1. Construction costs include aeration equipment and post aeration basin.
2. Designed to increase dissolved oxygen from 1 mg/l to 5 mg/l.
3. Detention time = 20 minutes.
4. Power information based on transfer of 34 lbs of O_2 per million gallons of wastewater treated.

References: 1, 7

FIGURE H-61 POST AERATION



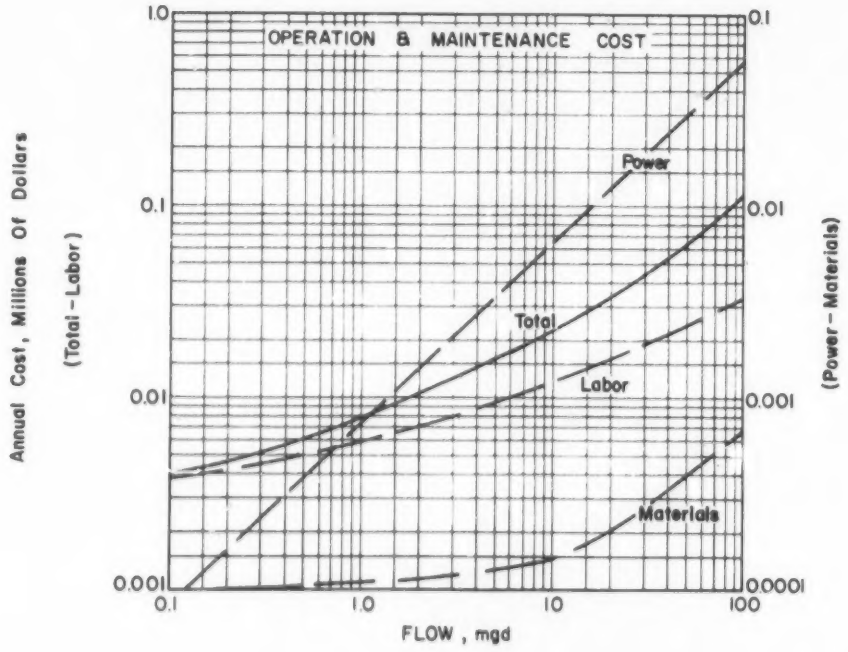


FIGURE H-62

GROUNDWATER RECHARGE (INFILTRATION)

Service Life: 30 years (equipment only); land assumed to have infinite life.

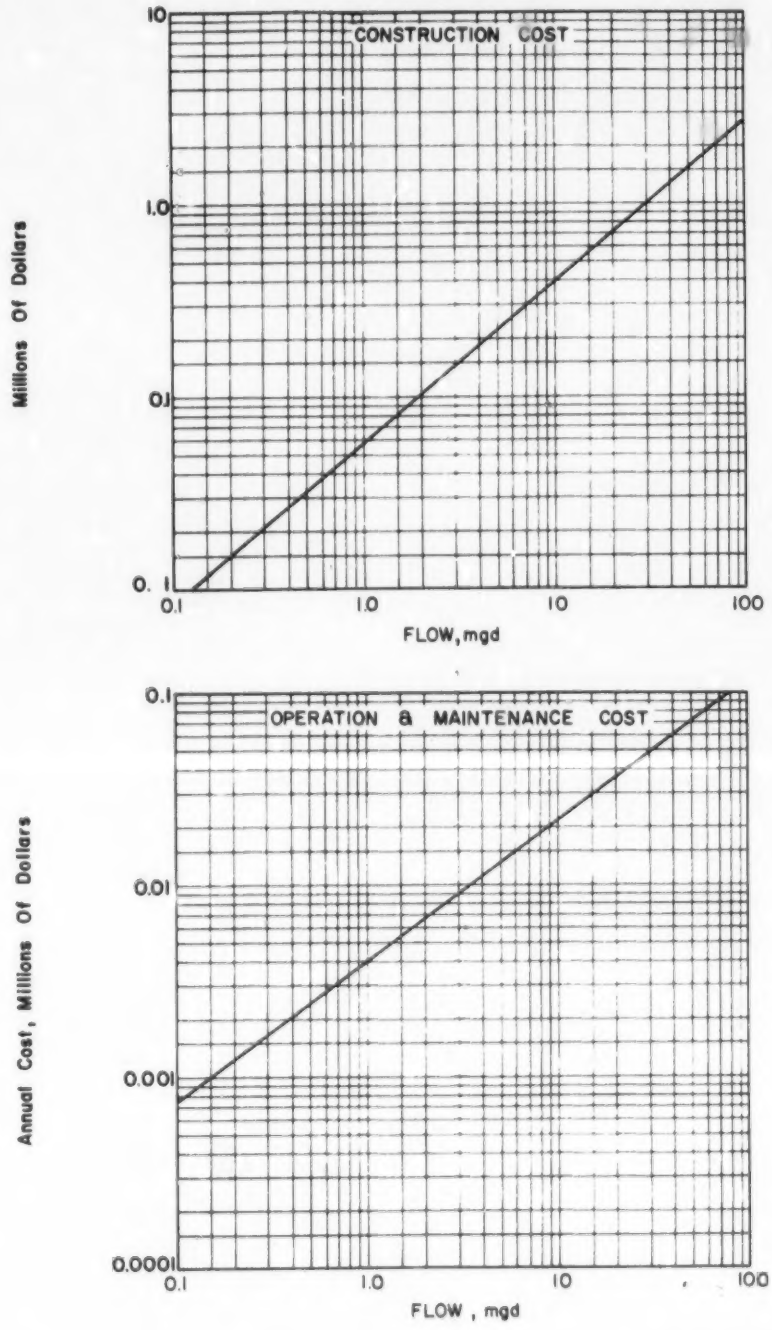
Relative Reliability: Level B

Design Basis:

1. Construction costs include site work, infiltration basin, gravel service road (12 ft), fence (4 ft) and on-site disposal of debris.

Reference: 27

FIGURE H-62 GROUNDWATER RECHARGE
(INFILTRATION)



H.8.4 Sludge Treatment and Disposal Processes: Cost Curves, Figures H-63 through H-83

FIGURE H-63

SLUDGE PUMPING

Service Life: 10 years

Relative Reliability: Level B

Design Basis:

1. Costs are based on a sludge loading of 1,900 lbs/mg at 4% solids, i.e., 5,700 gal of sludge/mg for combined primary and secondary sludge after thickening.
2. Non-clog centrifugal pumps.
3. TDH = 30 feet.

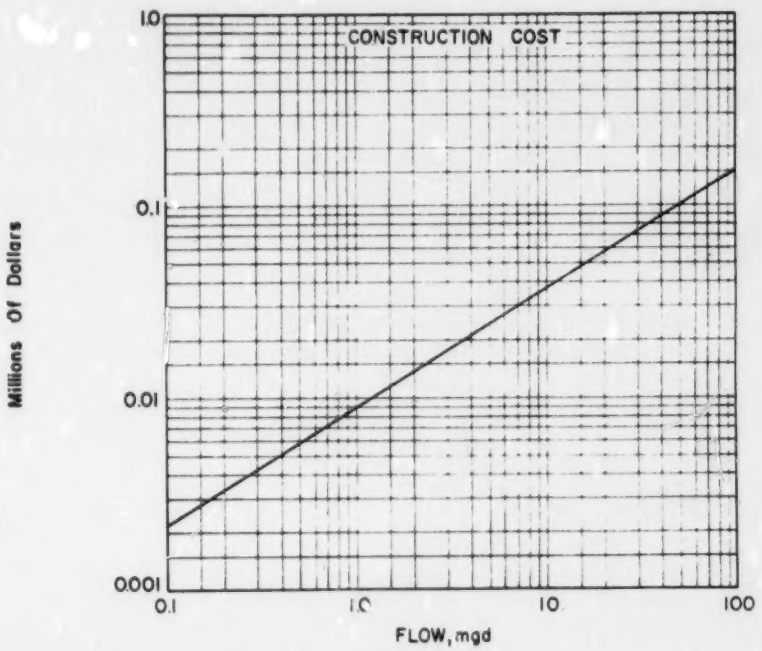
Adjustment Factor:

To adjust costs for alternative sludge quantities and characteristics, enter curves at effective flow (Q_E):

$$Q_E = Q_{DESIGN} \times \frac{\text{New Design Sludge Mass}}{1{,}900 \text{ lb/mg}} \times \frac{4\%}{\text{New Design Concentration (\%)}}$$

References: 4, 7

FIGURE H-63 SLUDGE PUMPING



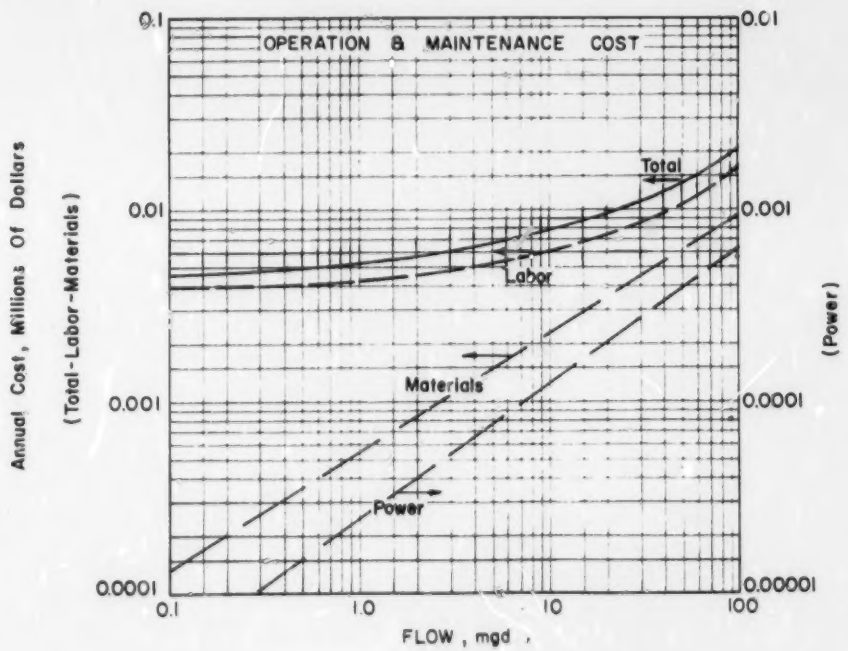


FIGURE H-64

GRAVITY THICKENER

Service Life: 50 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include thickener and all related mechanical equipment. Pumps are not included. (See Sludge Pumping Figure H-63.)

2. Costs are based on thickening of secondary sludge (820 lb/mg; loading = 6 lb/sq ft/day). See adjustment factors for other sludge loadings.

3. O & M costs do not include polymer or metal addition.

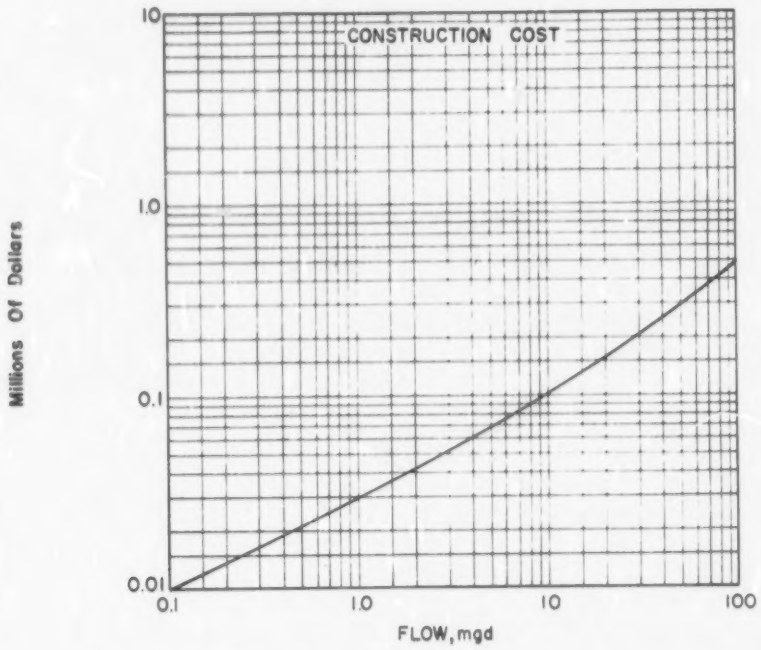
Adjustment Factor:

To adjust costs for alternative sludge quantites, concentrations, and thickening properties, enter curves at effective flow (Q_E)

$$Q_E = Q_{DESIGN} \times \frac{6 \text{ lb/sq ft/day}}{\text{New Design Mass Loading}} \times \frac{\text{New Design Sludge Mass}}{820 \text{ lbs/mg}}$$

References: 5, 6, 7, 13, 18

FIGURE H-64 GRAVITY THICKENER



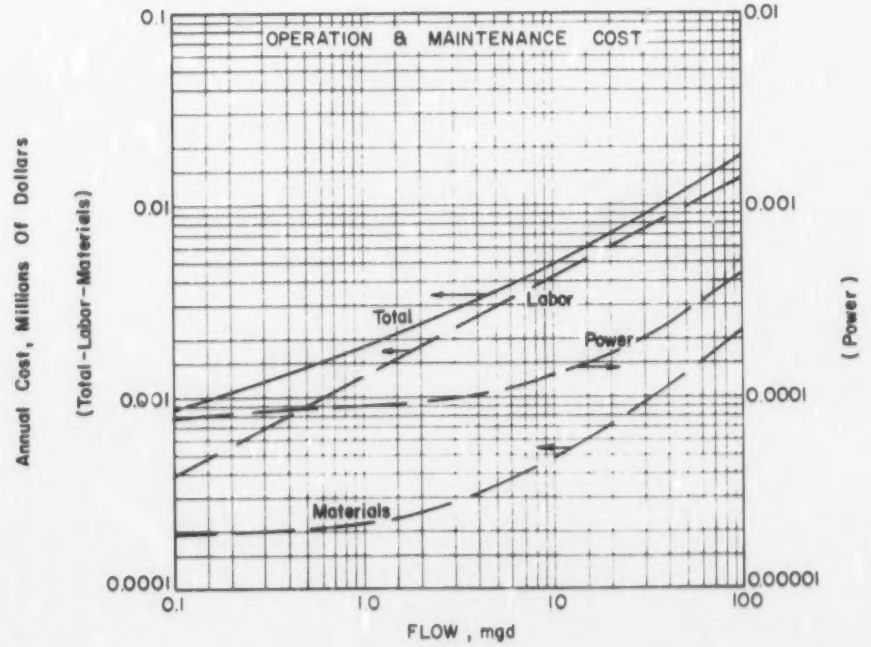


FIGURE H-65

DISSOLVED AIR FLOTATION THICKENER

Service Life: 40 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include:

   a. Flotation chamber (two-hour detention based on sludge flow).
   b. Pressure tanks (60 psig).
   c. Recycle pumps (100% recycle).

2. Costs for thickening of secondary sludge only: 820 lb/mg.

3. Loading rate = 2 lb/sq ft/hr.

4. Operating hours: 0.1 and 1 mgd = 40 hrs/wk; 10 mgd = 100 hrs/wk; 100 mgd = 168 hrs/wk.

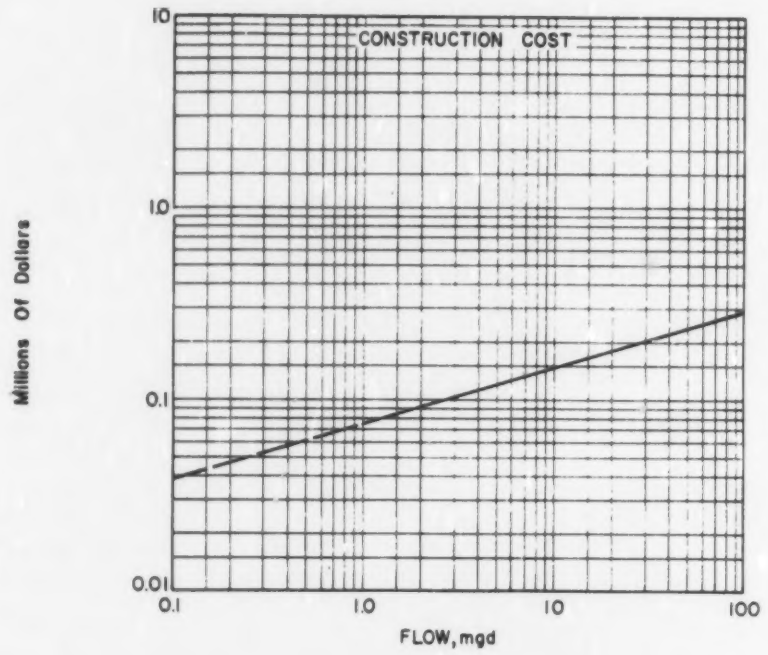
Adjustment Factor:

To determine costs at loading rates or sludge quantities other than above, enter curve at effective flow Q_E.

$$Q_E = Q_{DESIGN} \times \frac{2 \text{ lb/sq ft/hr}}{\text{New Design Mass Loading Rate}} \times \frac{\text{New Design Sludge Mass}}{820 \text{ lbs/day/mg}}$$

References: 5, 6, 8, 13, 18

FIGURE H-65 DISSOLVED AIR FLOTATION THICKENER



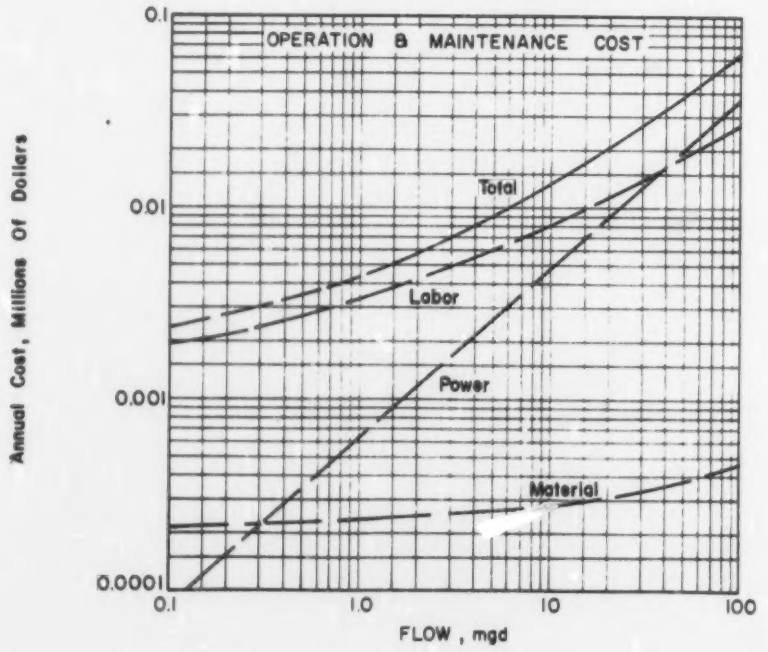


FIGURE H-66

CENTRIFUGATION (LIME SLUDGE DEWATERING)

Service Life: 20 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include: centrifuges (solid bowl), with minimum of one spare; sludge pumps and piping; cake conveyors, internal electrical and building cost.

2. Sludge quantity: 4,500 lb/mg at 10% solids.

3. Operation = 8 hrs/day.

4. Costs do not include centrate handling.

Adjustment Factor:

Costs for sludge quantities and characteristics are different than those for digested primary and secondary sludge. They are determined by entering curves at effective flow (Q_E).

$$Q_E = Q_{DESIGN} \times \frac{\text{New Design Sludge Mass}}{4{,}500 \text{ lbs/mg}} \times \frac{10\%}{\text{New Design Feed Sludge Concentration}}$$

References: 3, 5

FIGURE H-66 CENTRIFUGATION (LIME, SLUDGE DEWATERING)

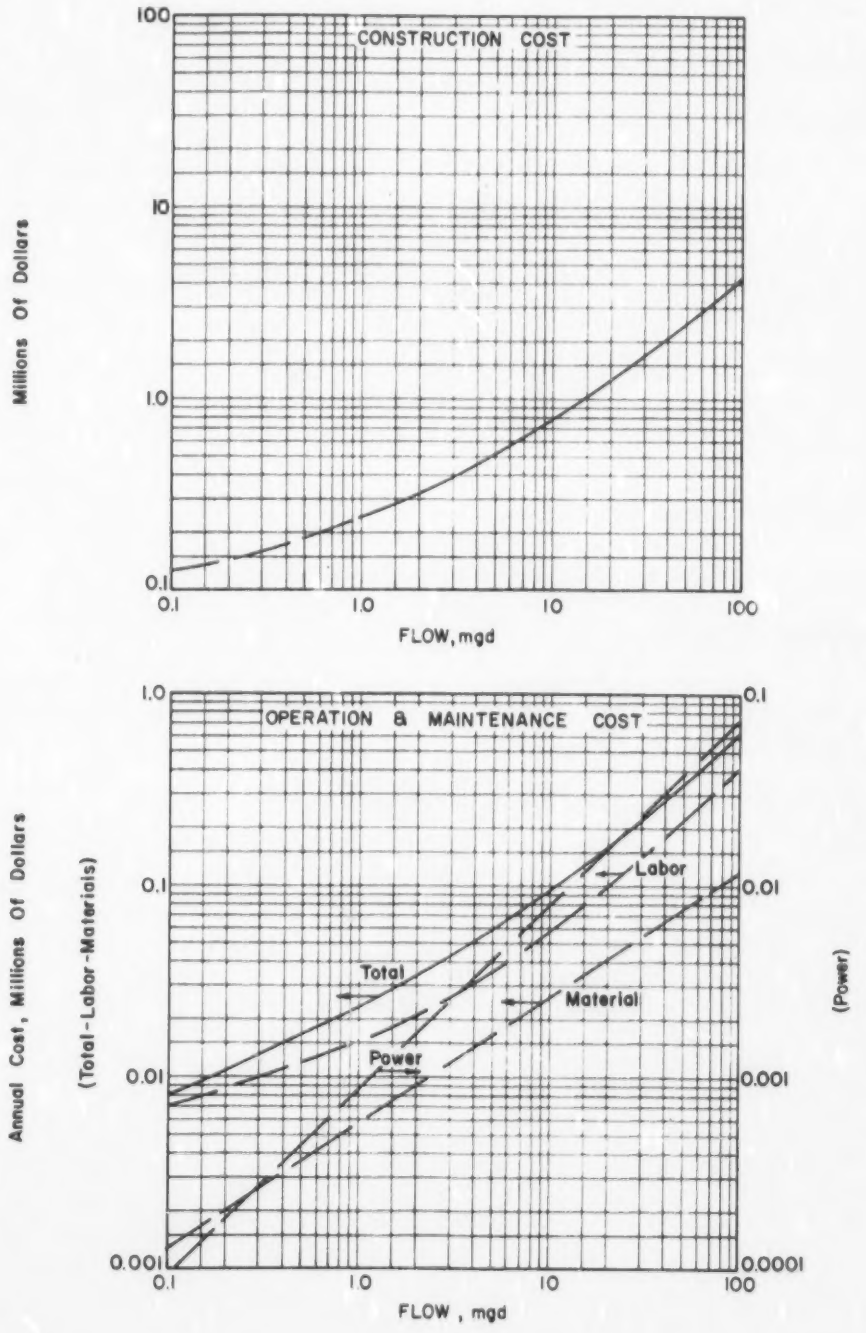


FIGURE H-67

CENTRIFUGATION (BIOLOGICAL SLUDGE DEWATERING)

Service Life: 20 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include: centrifuges with minimum of one spare unit; sludge pumps and piping; cake conveyors; and building costs.
2. Construction costs shown are for digested and undigested primary and secondary sludges.
3. O & M costs are for digested sludge.
4. Sludge quantity: digested primary and secondary sludge - 900 lb/mg at 4%.
5. Operation = 8 hrs/day.
6. Cationic polymer cost based on 10 lb/ton dry solids.

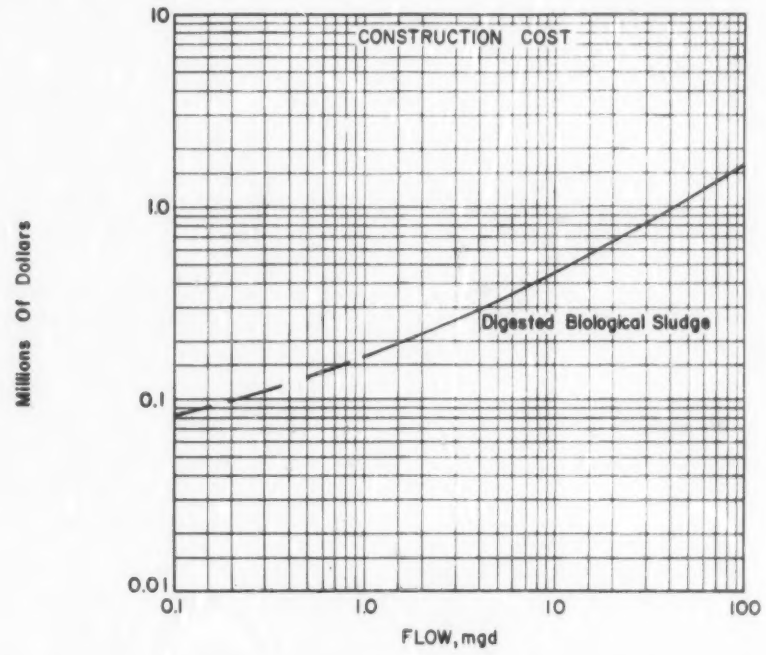
Adjustment Factor:

Costs for sludge quantities and characteristics are different than those for digested primary and secondary sludges. They are determined by entering curves at effective flow (Q_E).

$$Q_E = Q_{DESIGN} \times \frac{\text{New Design Sludge Mass}}{900 \text{ lbs/mg}} \times \frac{4\%}{\text{New Design Sludge Concentration}}$$

References: 3, 4, 5

FIGURE H-67 CENTRIFUGATION (BIOLOGICAL SLUDGE DEWATERING)



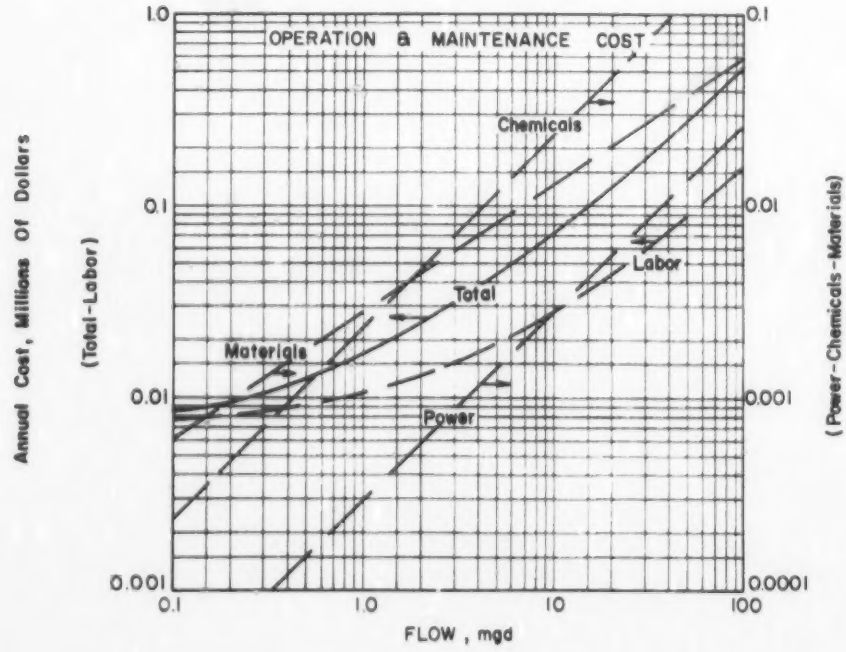


FIGURE H-68

VACUUM FILTRATION (BIOLOGICAL SLUDGE)

Service Life: 20 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include: pumps, internal piping and electrical controls; mechanical equipment, conveyors, and sludge cake storage hopper; building, chemical-handling, and storage facilities.

2. Costs are for dewatering of combined primary and secondary digested sludge - 900 lb/mg. See adjustment factor for dewatering other sludge.

3. Filter yield = 5 lb/sq ft/hr.

4. Operation time (excluding downtime for maintenance):

   6 hrs/day for 1-mgd plant or less.
   12 hrs/day for 10-mgd plant.
   18 hrs/day for 100-mgd plant.
   Interpolate for other plant sizes.

5. Chemical dosage: $FeCl_3$ = 35 lb/mg; CaO = 90 lb/mg.

Adjustment Factor:

Costs for sludge quantities and dewatering characteristics are different than those above. Enter curves at effective flow (Q_E).

$$Q_E = Q_{DESIGN} \times \frac{\text{New Design Sludge Mass}}{900 \text{ lbs/mg}} \times \frac{5 \text{ lbs/sq ft/hr}}{\text{New Design Mass Loading Rate}} \times \frac{\text{Original Design Operation Time}}{\text{New Design Operating Time}}$$

References: 3, 4, 7

FIGURE H-68 VACUUM FILTRATION (BIOLOGICAL SLUDGE)

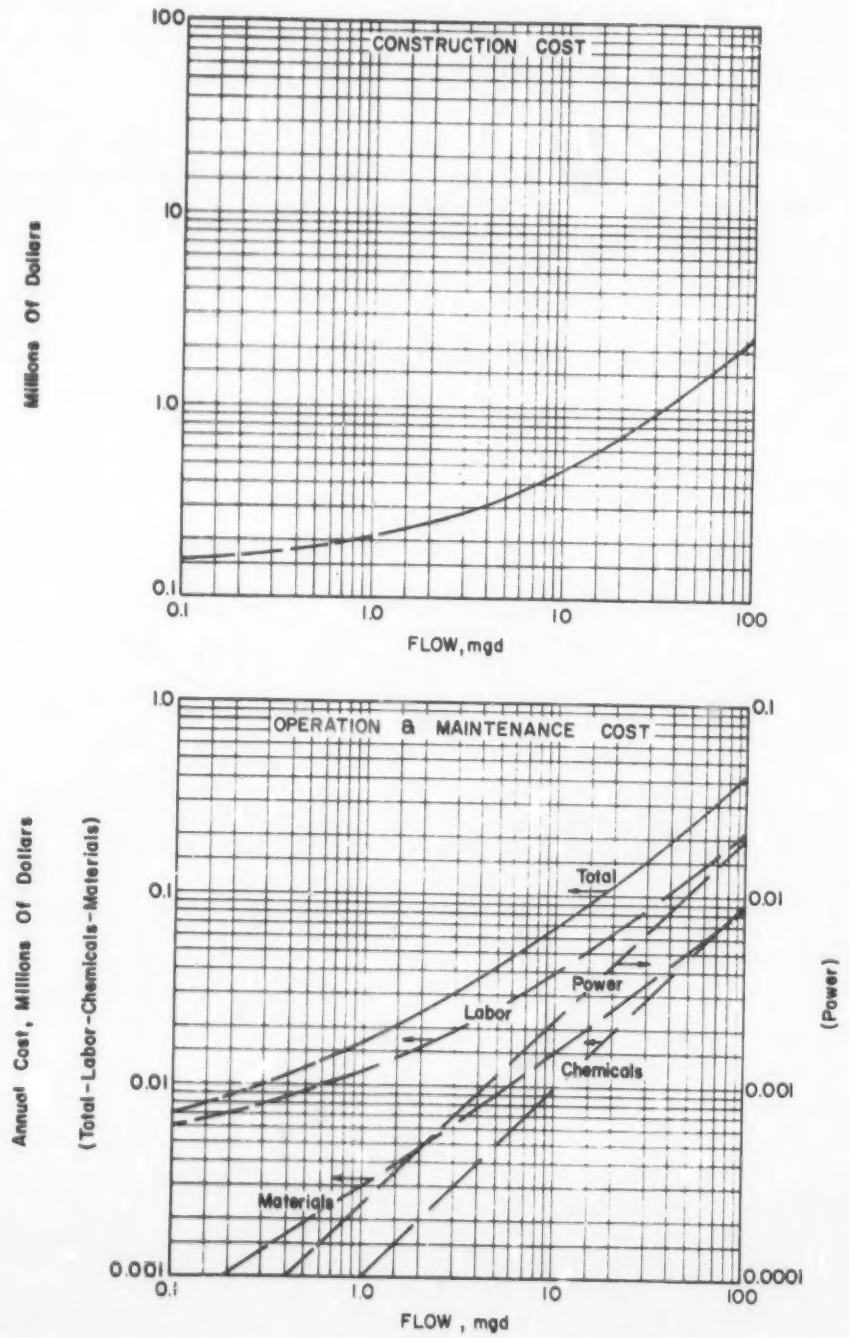


FIGURE H-69

VACUUM FILTRATION (LIME SLUDGE)

Service Life: 20 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include: pumps, internal piping and electrical, controls; mechanical equipment, conveyors, sludge-cake storage hopper; building.

2. Costs are for dewatering of lime sludge (4,500 lb/mg @ 10%).

3. Filter yield = 8 lb/sq ft/hr.

4. Operation time (excluding downtime for maintenance):

   6 hrs/day for 1-mgd plant or less.
   12 hrs/day for 10-mgd plant.
   18 hrs/day for 100-mgd plant.
   Interpolate for other plant sizes.

Adjustment Factor:

Costs for sludge quantities, concentrations, and dewatering characteristics or operating times are different than those above. Enter curves at effective flow (Q_E).

$$Q_E = Q_{DESIGN} \times \frac{\text{New Design Sludge Mass}}{4{,}500 \text{ lbs/mg}} \times \frac{8 \text{ lbs/sq ft/hr}}{\text{New Design Mass Loading Rate}} \times \frac{\text{Original Design Operation Time}}{\text{New Design Operation Time}}$$

References: 3, 4, 7

FIGURE H-69 VACUUM FILTRATION (LIME SLUDGE)

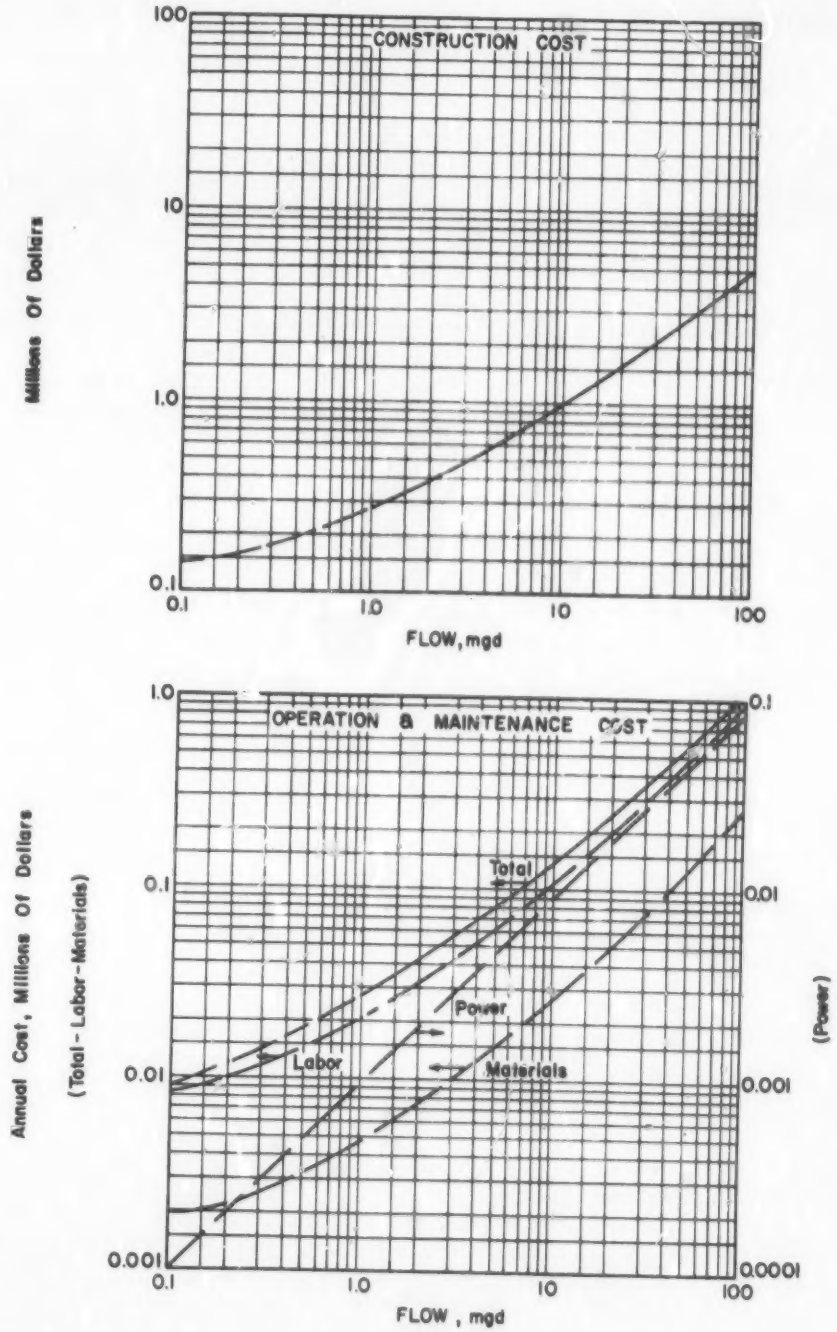


FIGURE H-70

FILTER PRESS (LIME SLUDGE)

Service Life: 15 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include: filter presses, pressure pumps, conveyor equipment, sludge storage tanks, and building.
2. Sludge loading: 4,500 lb/mg at 10%.
3. Cake characteristics: density = 75 lb/cu ft; solids content = 45%.
4. Operations: For 0.1 to 1 mgd plants - 20 cycles/week.
   For 1 to 10 mgd plant - 48 cycles/week.
   For 10 to 100 mgd plant - 84 cycles/week.
5. Cycle time: 2 hours/cycle.

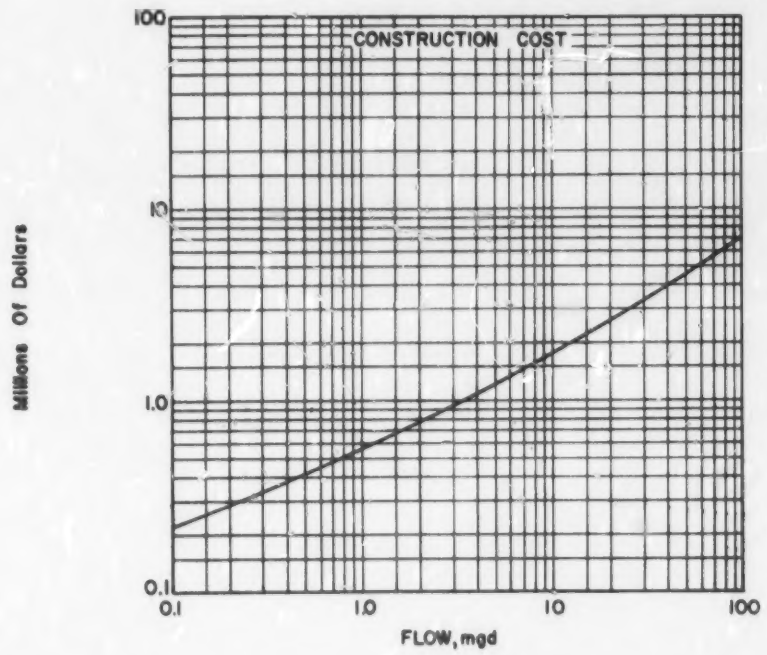
Adjustment Factor:

To develop cost for sludge quantities, concentrations, characteristics or cycles per week different than those used to develop these curves, enter curve at effective flow (Q_E).

$$Q_E = Q_{DESIGN} \times \frac{\text{New Design Sludge Mass}}{4{,}500 \text{ lbs/mg}} \times \frac{\text{Original Design Cycles Per Week}}{\text{New Design Cycles Per Week}} \times \frac{\text{New Design Cycle Time}}{2 \text{ hours}}$$

References: 5, 18

FIGURE H-70 FILTER PRESS (LIME SLUDGE)



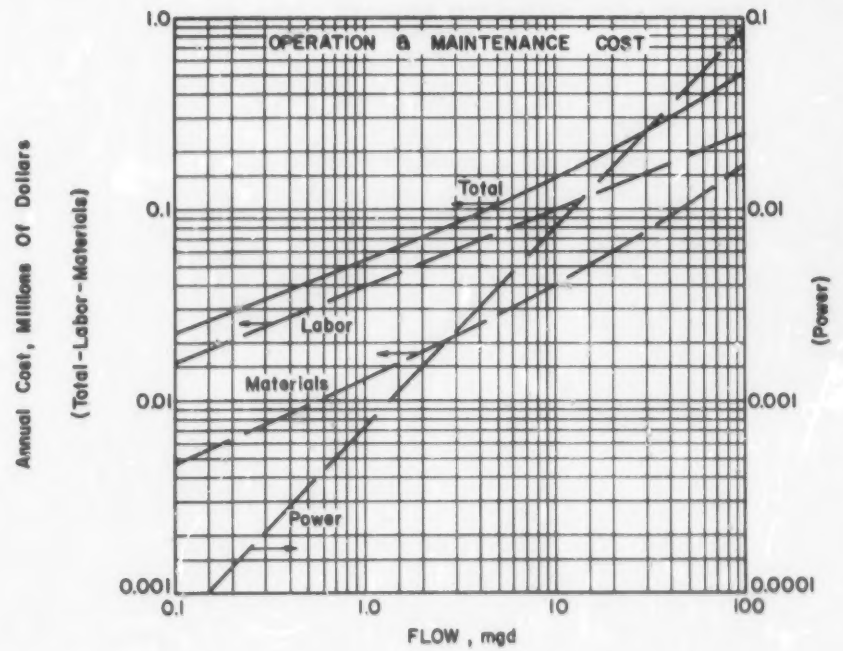


FIGURE H-71

FILTER PRESS (BIOLOGICAL SLUDGE)

Service Life: 15 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include: filter presses, pressure pumps, conveyor equipment, chemical feed and storage facilities, conditioning tanks, sludge storage tanks, and building.

2. Sludge loading: digested primary + secondary = 900 lb/mg @ 2.5%

3. Cake characteristics: density = 65 lb/cu ft; solids content = 40%

4. Operations: For 0.1 to 1 mgd plants - 20 cycles/week
   For 1 to 10 mgd plant - 48 cycles/week
   For 10 to 100 mgd plant - 84 cycles/week

5. Conditioning chemicals: $FeCl_3$ = 35 lb/mg; CaO = 90 lb/mg.

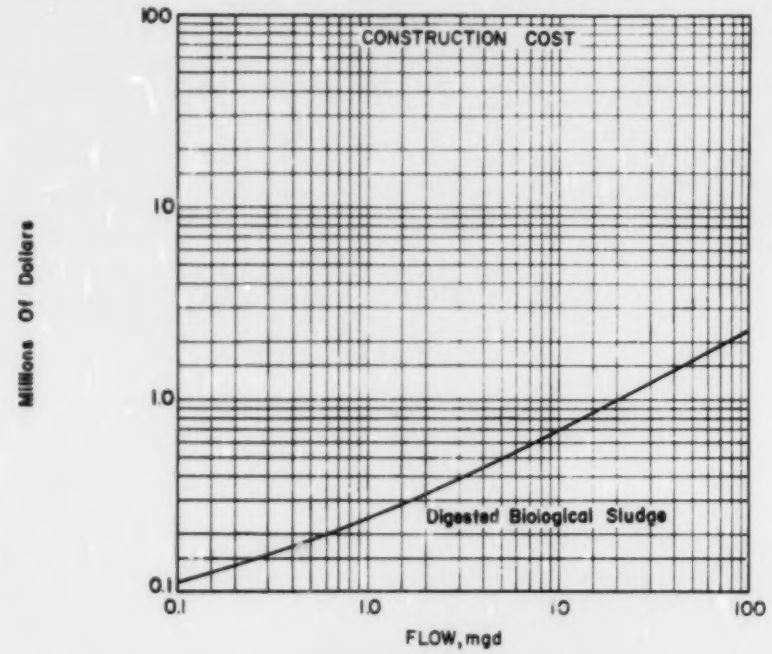
Adjustment Factor:

To develop cost for sludge quantities, concentrations, characteristics or cycles per week different than those used to develop these curves, enter curve at effective flow (Q_E).

$$Q_E = Q_{DESIGN} \times \frac{\text{New Design Sludge Mass}}{900 \text{ lb/mg}} \times \frac{\text{Original Design Cycles Per Week}}{\text{New Design Cycles Per Week}} \times \frac{\text{New Design Cycle Time}}{2 \text{ hours}}$$

References: 5, 18

FIGURE H-71 FILTER PRESS (BIOLOGICAL SLUDGE)



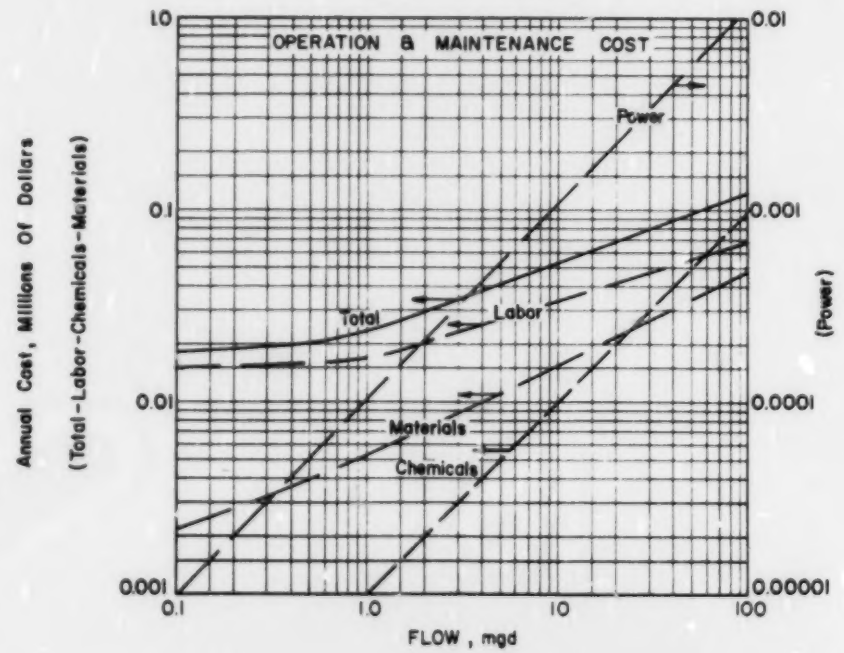


FIGURE H-72

SLUDGE DRYING BEDS

Service Life: 20 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include: sand beds, sludge inlets, underdrains, cell dividers, sludge piping, underdrain return, and other structural elements of the beds.

2. Bed loading: 900 lb of sludge/mg; 20 lb/sq ft/year.

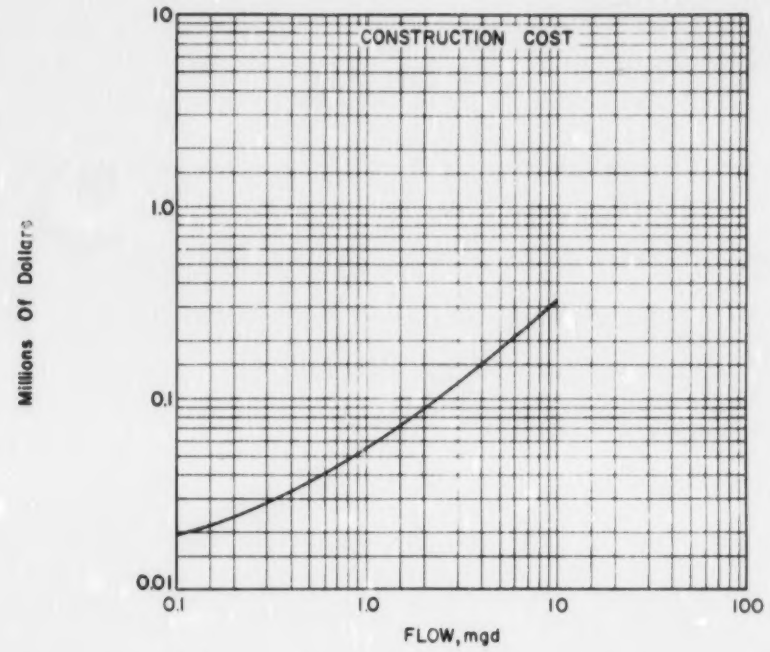
Adjustment Factor:

To adjust costs for bed loading rates, sludge quantities, or characteristics, enter curve at effective flow (Q_E).

$$Q_E = Q_{DESIGN} \times \frac{\text{New Design Sludge Mass}}{900 \text{ lb/mg}} \times \frac{20 \text{ lb/sq ft/yr}}{\text{New Design Bed Loading}}$$

References: 3, 5

FIGURE H-72 SLUDGE DRYING BEDS



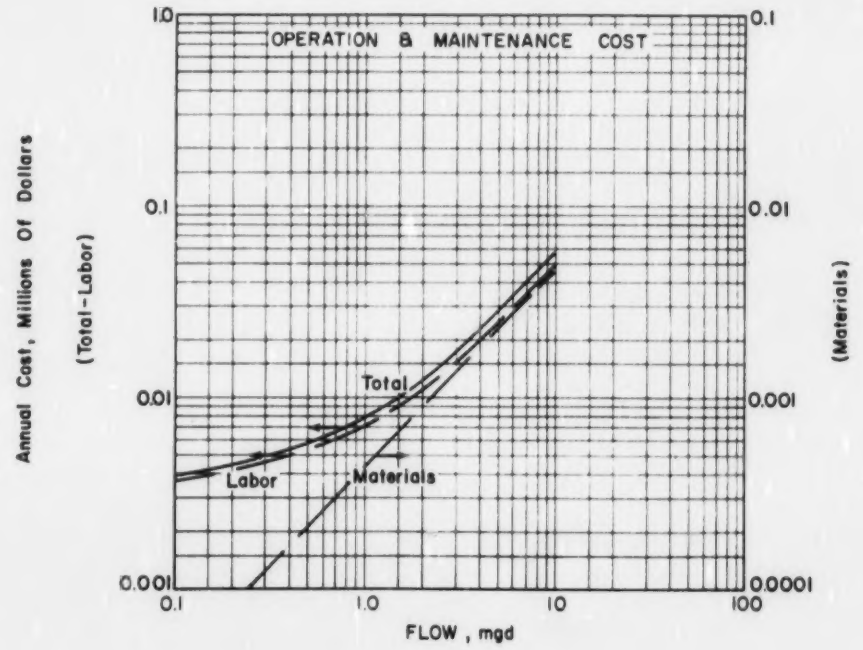


FIGURE H-73

TWO-STAGE ANAEROBIC DIGESTERS

Service Life: 50 years

Relative Reliability: Level B

Design Basis:

1. Capital costs include: digester, heat-exchanger, gas-collection equipment, control building.
2. Feed to digesters is combined primary and is thickened.
3. Feed - 1,900 lb/mg at 4% solids (75% volatile).
4. Effluent from digesters is 900 lb/mg at 2.5% solids.
5. Loading rate - 0.16 lb/cu ft/day.
6. Operating temperature - 85 to 110°F.
7. Digester gas is utilized for heating. Excess gas is not utilized.

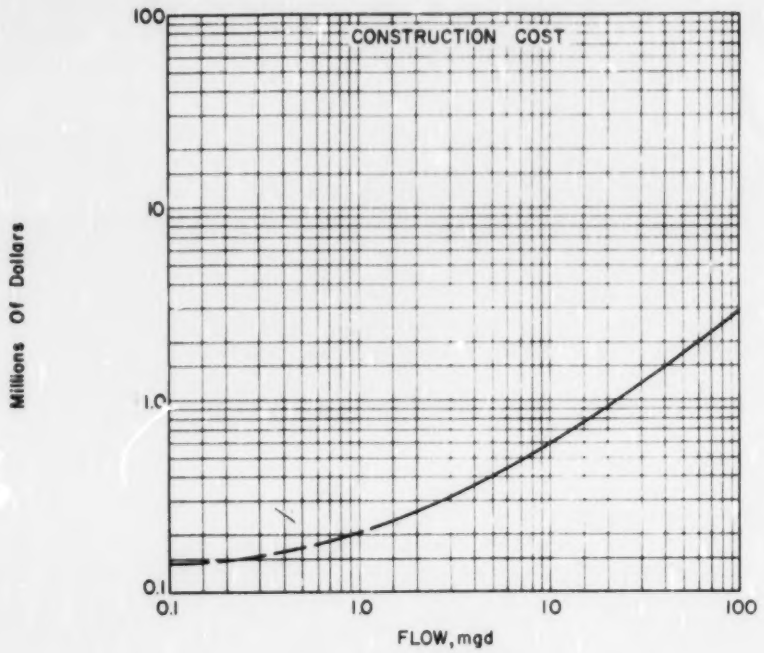
Adjustment Factor:

To adjust costs for loading rates different than those presented here, enter curve at effective flow (Q_E).

$$Q_E = Q_{DESIGN} \times \frac{\text{New Design Sludge Mass}}{1{,}900 \text{ lb/mg}}$$

References: 7, 8, 10, 13

FIGURE H-73 TWO STAGE ANAEROBIC DIGESTERS



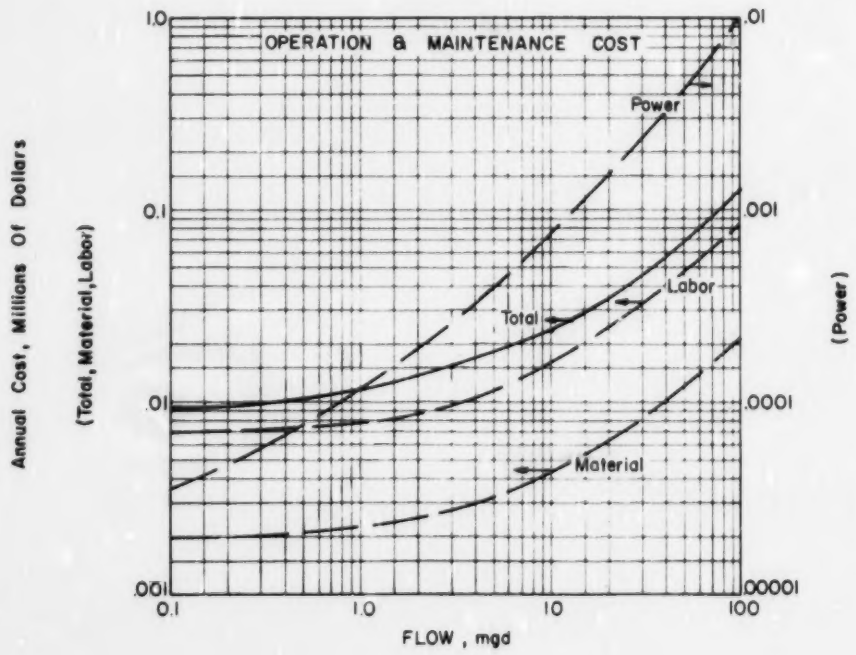


FIGURE H-74

AEROBIC DIGESTERS

Service Life: 40 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include:

   a. Basins (20 day detention time) - sludge flow = 5,700 gal/mg (1900 lb/mg at 4%)

   b. Floating mechanical aerators

2. Mixing requirements: 134 hp/mg.

3. Oxygen requirements: 1.6 lbs O_2/lb VSS destroyed.

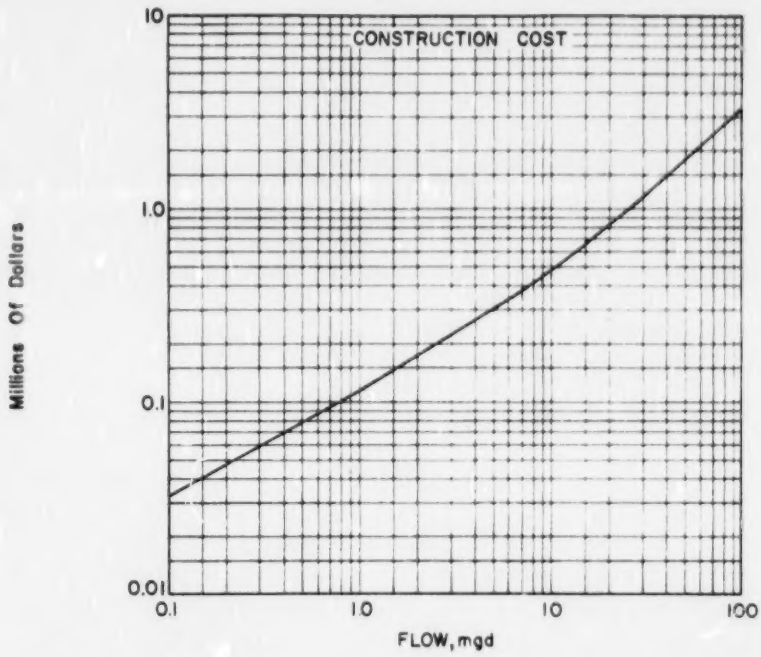
Adjustment Factor:

To adjust costs for design factors different from those above, enter curves at effective flow (Q_E).

$$Q_E = Q_{DESIGN} \times \frac{20 \text{ days}}{\text{New Design Retention Time}} \times \frac{\text{New Design Sludge Mass}}{1{,}900 \text{ lb/mg}} \times \frac{4\%}{\text{New Design Sludge Concentration}}$$

References: 6, 13

FIGURE H-74 AEROBIC DIGESTERS



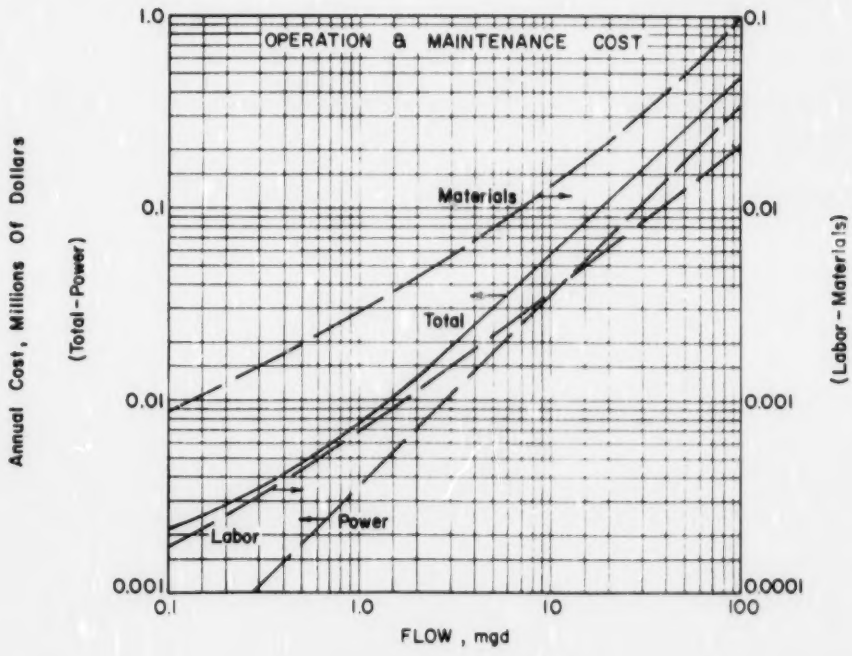


FIGURE H-75

HEAT TREATMENT OF SLUDGE

Service Life: 25 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include: sludge feed pumps, grinders, heat exchangers, reactors, boilers, gas separators, and buildings.

2. Costs are related to average wastewater flow by the following:

   a. Sludge quantity = 1900 lbs/mg (undigested, combined thickened primary plus secondary sludge).

   b. Solids concentration = 4.5%

   c. Sludge flow = 3.8 gpm/mgd based on 8,000 operating hrs per year

3. Fuel costs are for steam generation.

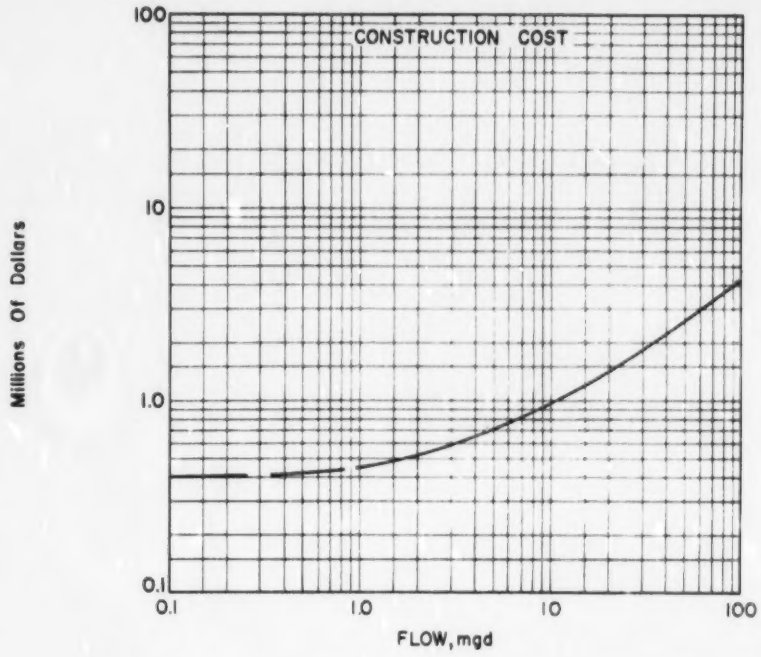
Adjustment Factor:

To adjust costs for design factors different than for those above, enter curve at effective flow (Q_E).

$$Q_E = Q_{DESIGN} \times \frac{\text{New Design Sludge Mass}}{1{,}900 \text{ lb/mg}}$$

References: 4, 23

FIGURE H-75 HEAT TREATMENT OF SLUDGE



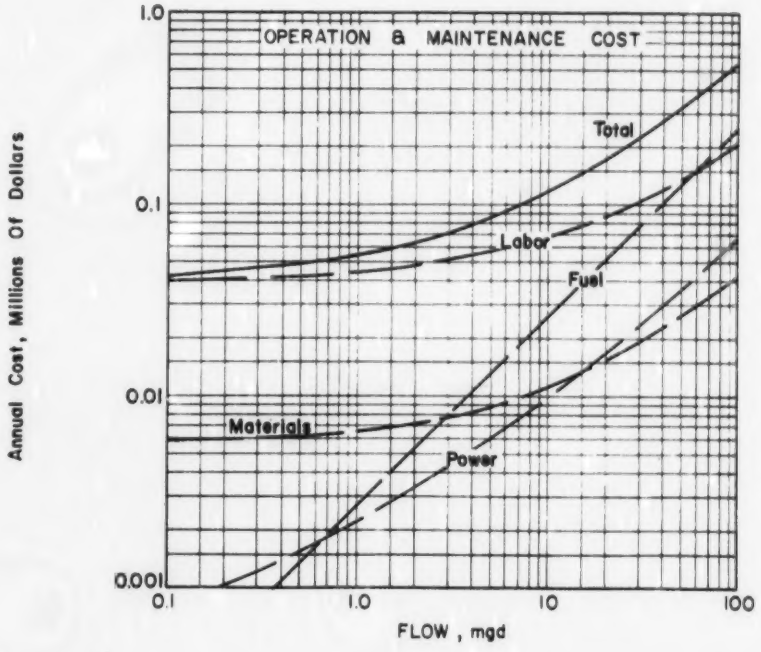


FIGURE H-76

COMPOSTING

Service Life: 17 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include: asphalt pad, roads, sewer, drainage pond, electrical work, engineering. Do not apply cost multipliers shown in Table H-2.

2. Sludge production rate: 900 lb/mg.

3. Land Requirement: 0.35 acres/(ton/day).
   Assumed land cost = $10,500/acre.

4. Costs apply to composting of digested or raw biological sludge.

Adjustment Factor:

To adjust cost for sludge composting rates different than 900 lb/mg enter cost curves at effective flow (Q_E).

$$Q_E = Q_{DESIGN} \times \frac{\text{New Design Sludge Mass}}{900 \text{ lb/mg}}$$

References: 53

FIGURE H-76 COMPOSTING

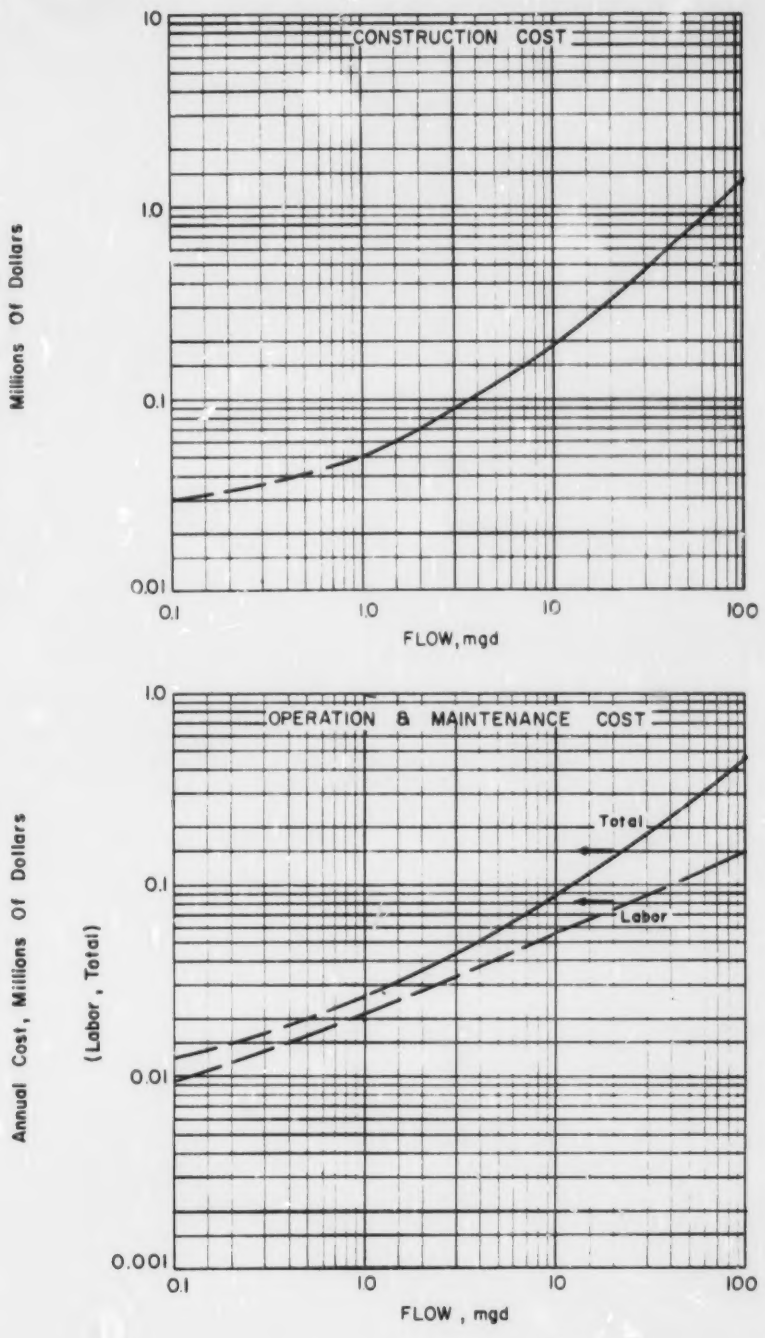


FIGURE H-77

INCINERATION (FLUIDIZED BED)

Service Life: 30 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include: reactor, air blowers and accessories, preheater, scrubbers, fuel pumps, building.

2. Costs are for undigested dewatered primary and secondary sludge (1,900 lb/mg at 20% solids; 75% volatile).

3. Operations:

Flow mgd	Day/Week Operating	Hrs/Day
0.1	1	20
1.0	7	20
10.0	7	20
100.0	7	20

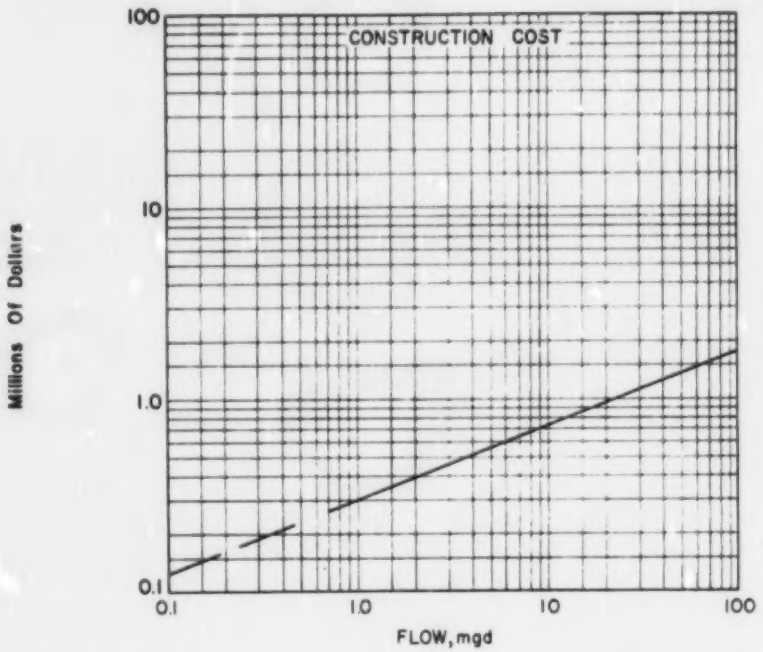
4. Fuel requirements = 100 - 120 gal No. 2 fuel oil/dry ton sludge.

Adjustment Factor:

Fuel costs for conditions different than those given above may be adjusted. However, the relationship of fuel requirements and operating conditions are too complicated to allow for simple adjustment here. Specific detailed study is suggested for each case.

References: 9, 21, 22, 34

FIGURE H-77 INCINERATION (FLUIDIZED BED)



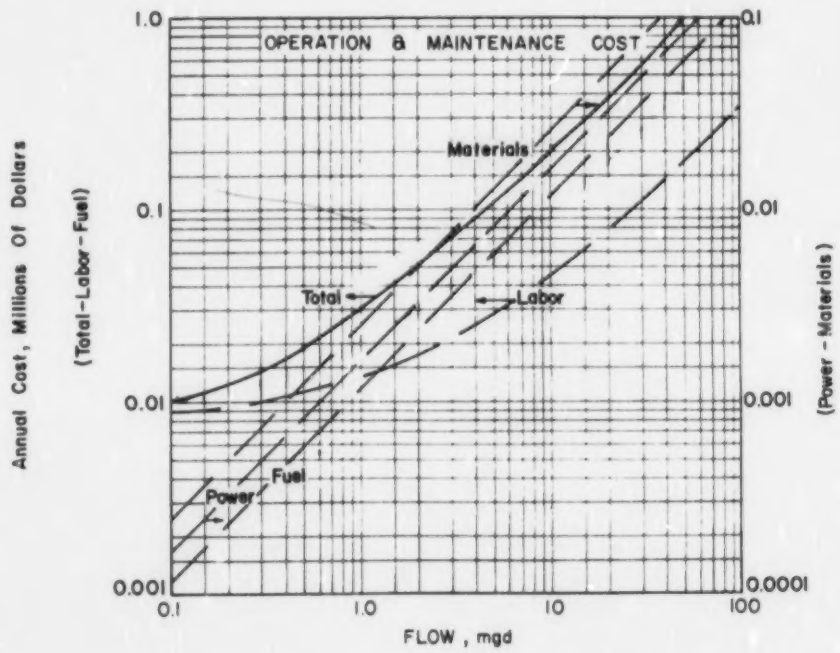


FIGURE H-78

INCINERATION (MULTIPLE HEARTH)

Service Life: 30 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include: incinerator, building, sludge conveyor, ash-handling equipment, gas scrubbers.

2. Costs are for undigested dewatered primary and secondary sludge (1,900 lb/mg at 20% solids; 75% volatile).

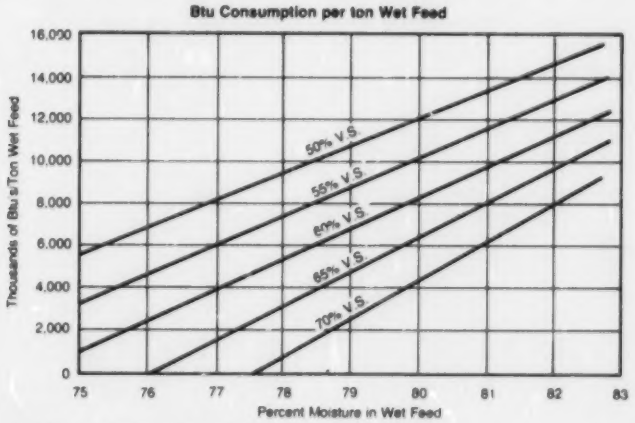
3. Operations:

Flow mgd	Day/Week Operating	Hrs/Day
0.1	1	20
1.0	7	20
10.0	7	20
100.0	7	20

4. Fuel requirements for warm-up and incineration = 32,000 gal of No. 2 fuel oil/yr/mgd.

Adjustment Factor:

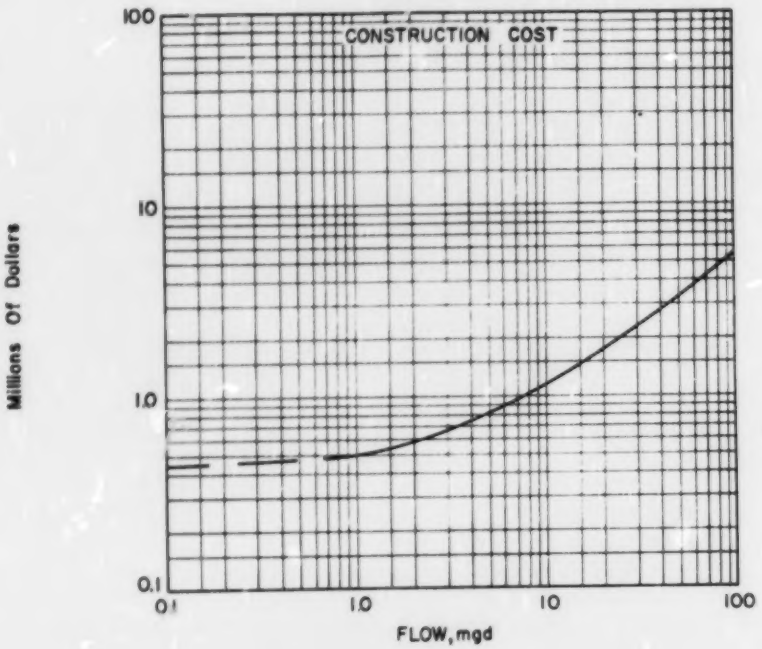
To adjust fuel costs of other than those listed, use graph below.



NOTES: 1. Curves are only applicable for continuous operation at feed rates above 4 tons per hour.
2. Sludge heat content is 10,000 btu/lb volatile solids.

References: 3, 4, 5, 8, 9, 13

FIGURE H-78 INCINERATION (MULTIPLE HEARTH)



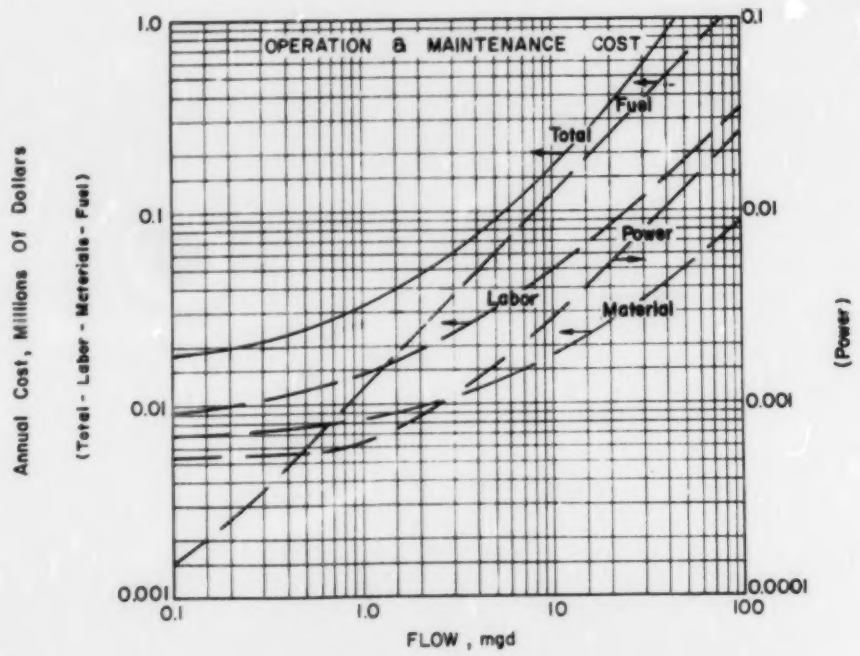


FIGURE H-79

LIME STABILIZATION

Service Life: 20 years

Relative Reliability: Level B

Design Basis:

1. Construction cost includes:

   a. Two volumetric feeder systems with manually loaded bins, dissolving chambers, and accessories for plants less than 1.5 mgd.

   b. For plants larger than 1.5 mgd, two gravimetric feeder-slaker systems and steel bins to hold 1½ truckloads of quick lime each.

   c. For plants larger than 25 mgd, four gravimetric feeder-slaker systems with bin gates and accessories.

   d. Sludge holding tank (3 days detention time).

2. Operations and maintenance costs include:

   a. Slaker - 1 hour of operation/slaker/shift in use.
   b. Feeder - 10 minutes of operation/hour/feeder.
   c. Slurry Pot - feed line (for slake lime) - 4 hours/week.
   d. Power requirements of 7.0 kwh/1,000 lbs lime.

3. Use hydrated lime ($Ca(OH)_2$) for plants less than 1.5 mgd.

4. Use quicklime (CaO) for plants larger than 1.5 mgd.

5. Sludge mass is 1900 lbs dry solids/mg for thickened primary and secondary sludge at 4% solids.

6. Lime dosage is 212 lb (as CaO)/ton of dry solids.

References: 13, 18, 50

FIGURE H-79 LIME STABILIZATION

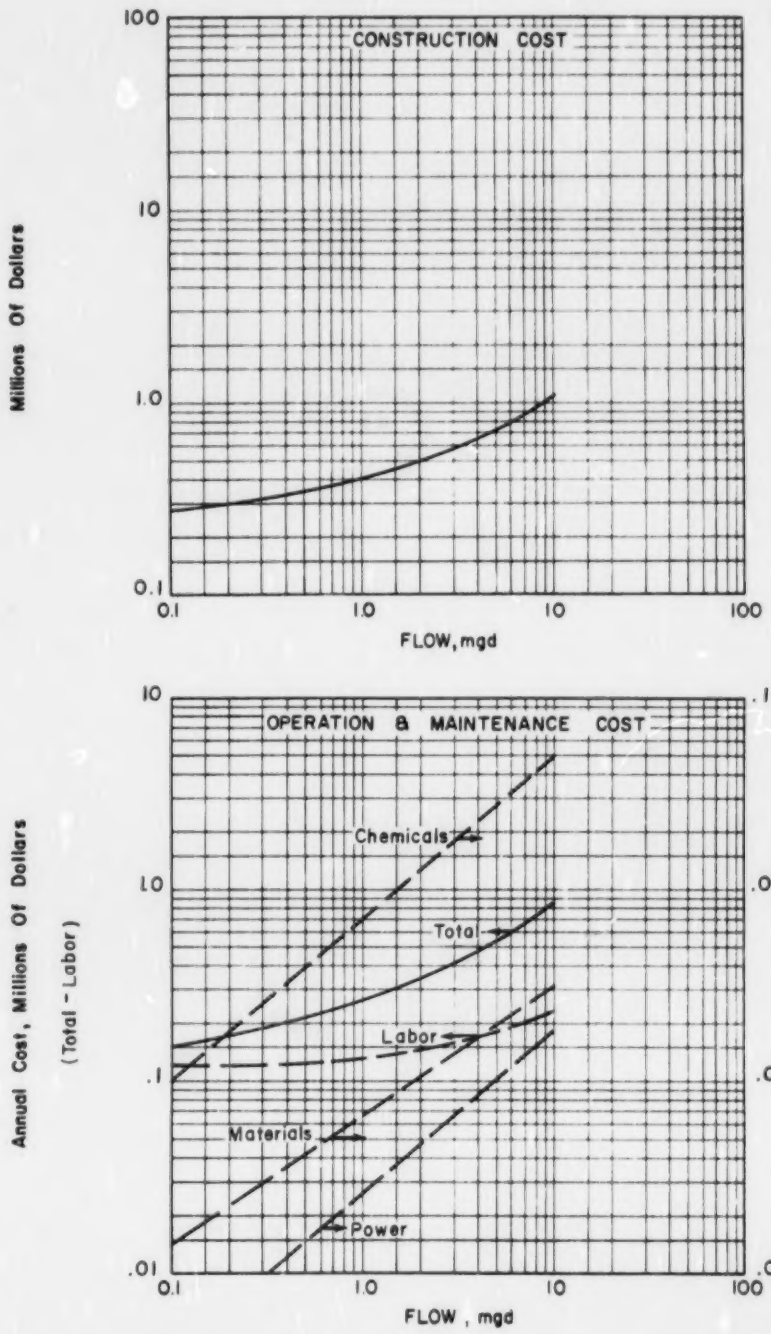


FIGURE H-80

SLUDGE STORAGE

Service Life: 30 years

Relative Reliability: Level B

Design Basis:

1. Costs are for storage of thickened primary and secondary sludge (1,900 lb/mg; at 4% solids).
2. Mixing by diffused air (25 cfm/1,000 cu ft, or approximately 130 hp/mg).
3. Construction costs include: storage tank and air-supply system for mixing and aeration.

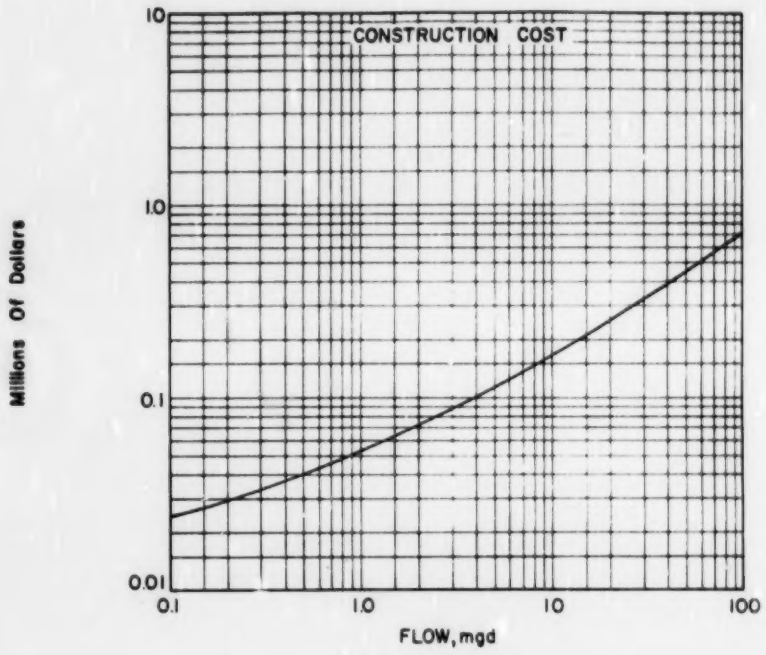
Adjustment Factor:

To adjust costs for other sludge quantities and concentrations, enter the curves at effective flow (Q_E).

$$Q_E = Q_{DESIGN} \times \frac{\text{New Design Sludge Mass}}{1{,}900 \text{ lbs/mg}} \times \frac{4\%}{\text{New Design Sludge Concentrations}}$$

References: 3, 7, 9, 13

FIGURE H-80 SLUDGE STORAGE



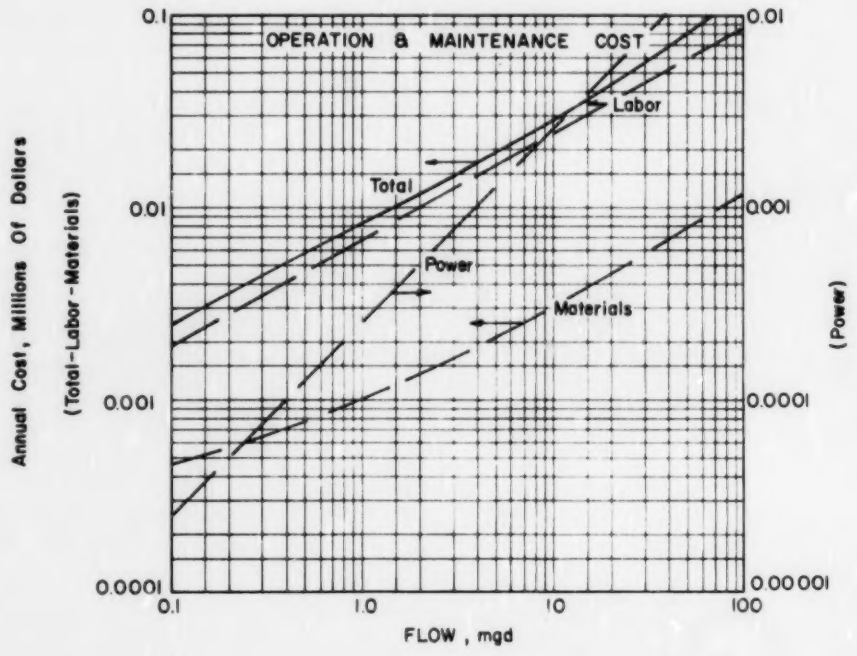


FIGURE H-81

LANDFILLING (BIOLOGICAL SLUDGE EXCLUDING TRANSPORTATION)

Service Life: 20 years

Relative Reliability: Level B

Design Basis:

1. Construction costs do not include cost for land (1.1 acres/mgd including allowance for 25% of volume for cover and 10% loss of surface area for roads and buffer zone).

2. Construction costs include: site preparation, front end loaders, monitoring wells, fencing, leachate collection and treatment.

3. Operation and maintenance costs include:

   a. Labor costs for operation, preventive maintenance, and minor repairs.

   b. Material costs to include replacement parts, soil for mixing with sludge (1 part soil to 3 parts sludge), fuel for bulldozer operation, and repair work performed by outside contractors.

4. Costs are for landfilling of dewatered and digested biological sludge. Costs for landfilling of other predominantly biological sludges can be obtained by using the adjustment factor.

5. Sludge quantity = 900 lb/mg at 20% solids; 2.7 cu. yd/mg.
   Note: at 20% concentration, may require blending with soil.

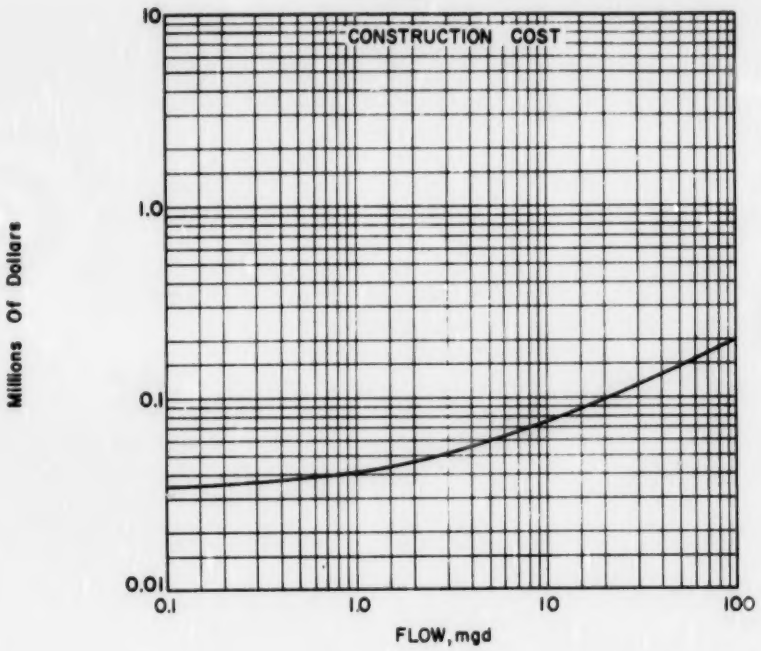
Adjustment Factor:

For sludge quantities and concentrations other than those listed above, enter curve at effective flow (Q_E).

$$Q_E = Q_{DESIGN} \times \frac{\text{New Design Sludge Mass}}{900 \text{ lb/mg}} \times \frac{20\%}{\text{New Design Sludge Concentration}}$$

References: 9, 32

FIGURE H-81 LANDFILLING (BIOLOGICAL SLUDGE, EXCLUDING TRANSPORTATION)



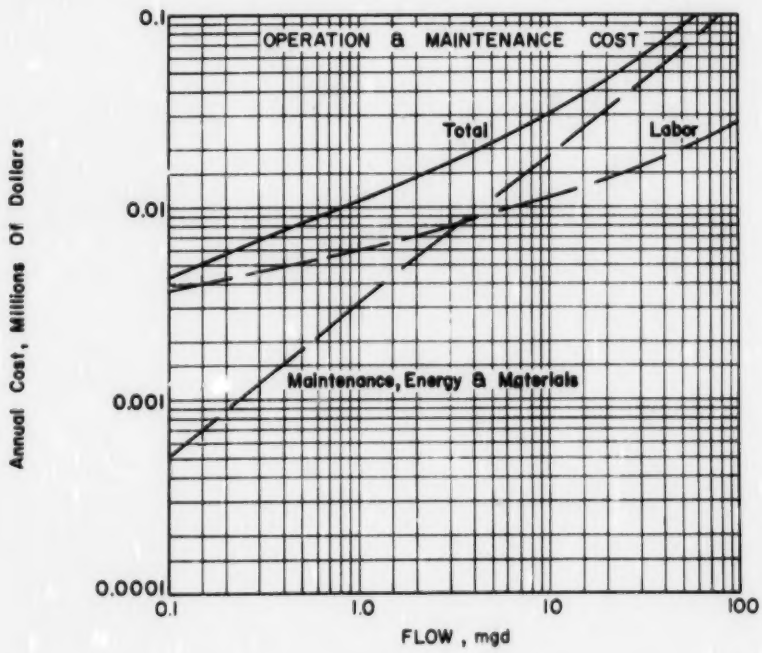


FIGURE H-82

LANDFILLING (LIME SLUDGE EXCLUDING TRANSPORTATION)

Service Life: 20 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include: site preparation, bulldozers, monitoring wells, fencing, and leachate collection and treatment.

2. Construction costs do not include cost for land (3.1 acres/mgd; including allowance for 25% of volume for cover and 10% loss of surface area for roads and buffer zone).

3. Operation and maintenance costs include:

   a. Labor costs for operation, preventive maintenance, and minor repairs.

   b. Material costs to include replacement parts, soil for mixing with sludge (1 part soil to 3 parts sludge), fuel for bulldozer operation, and repair work performed by outside contractors.

4. Lime sludge quantity = 4,500 lb/mg at 30%; 7.4 cu yd/mg.

Adjustment Factor:

To adjust costs for other sludge quantities and concentrations, enter the curves at effective flow (Q_E).

$$Q_E = Q_{DESIGN} \times \frac{\text{New Design Sludge Mass}}{4{,}500 \text{ lb/mg}} \times \frac{30\%}{\text{New Design Concentration}}$$

References: 9, 32

FIGURE H-82 LANDFILLING (LIME SLUDGE, EXCLUDING TRANSPORTATION)

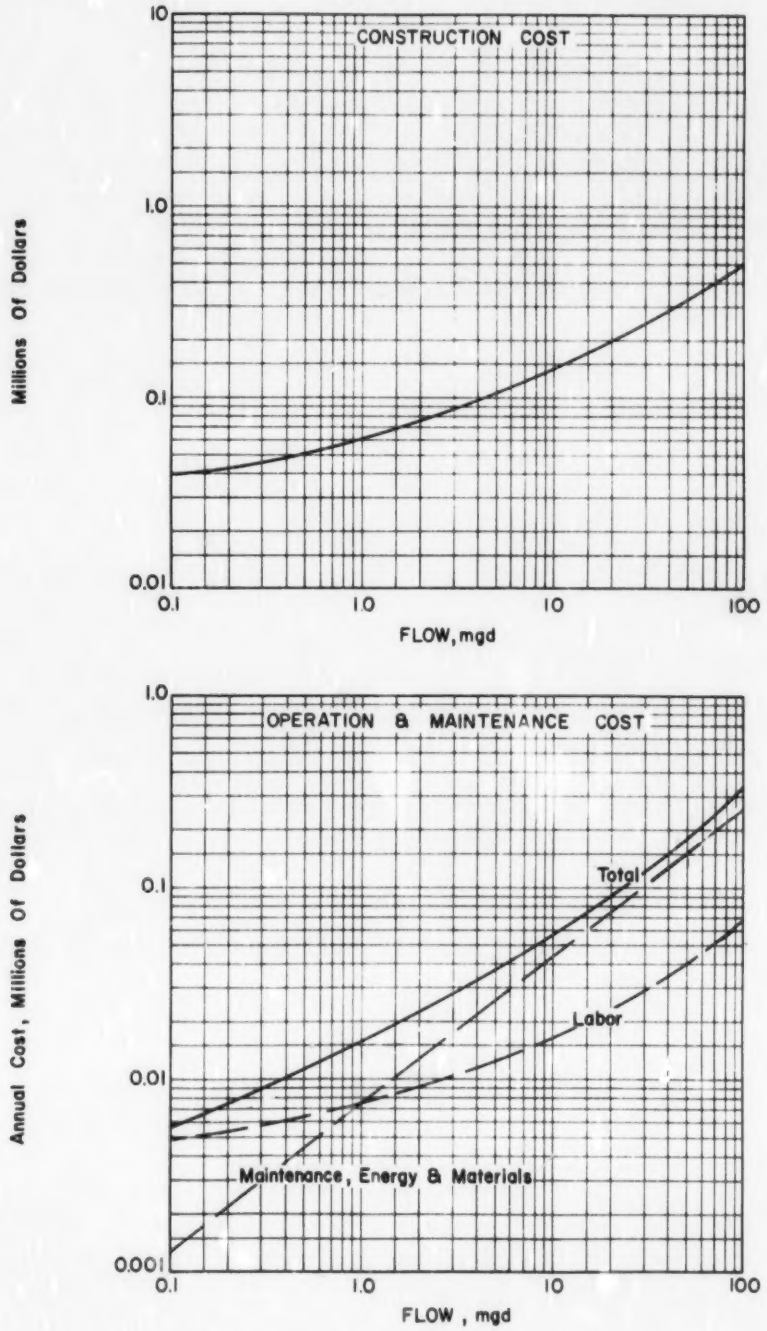


FIGURE H-83

LAND APPLICATION OF SLUDGE

Service Life: 30 years

Relative Reliability: Level B

Design Basis:

1. Construction costs include: storage lagoon (6 weeks); land preparation, monitoring wells (3 at 0.1 mgd, 5 at 1 mgd, 8 at 10 mgd, 25 at 100 mgd, and services roads.

2. Costs are for application of digested biological sludge - 900 lb/mg at 4% solids.

3. Transport of sludge to site is included in the appropriate transportation curve. (See Figures H-86 through H-90.)

4. Sludge application rate - 10 ton (dry)/acre/year.

5. Land costs are not included.

6. Sludge application is by subsurface injection - unit attached to haul truck.

7. Operation and maintenance costs include:

   a. Labor costs for sludge operation, preventive maintenance, and minor repairs.

   b. Material costs to include replacement of parts and repair performance by outside contractors.

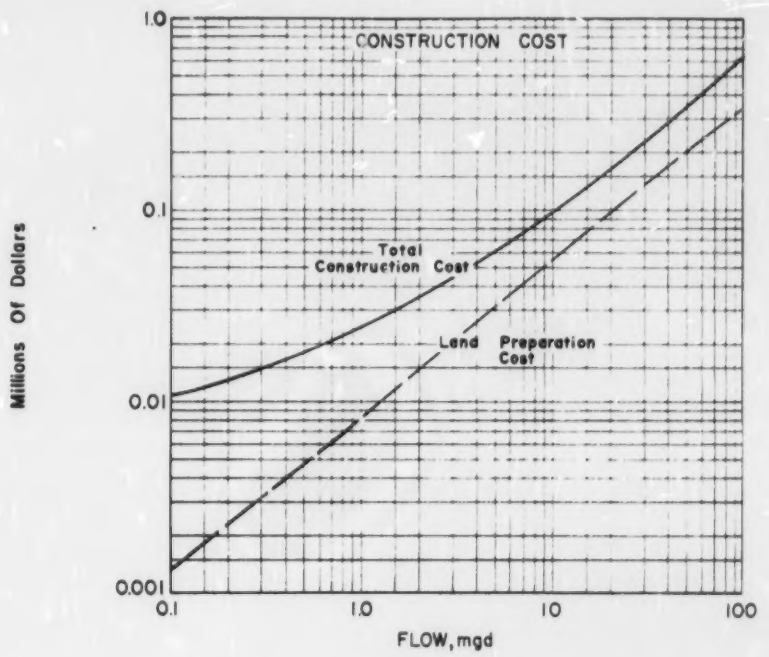
Adjustment Factor:

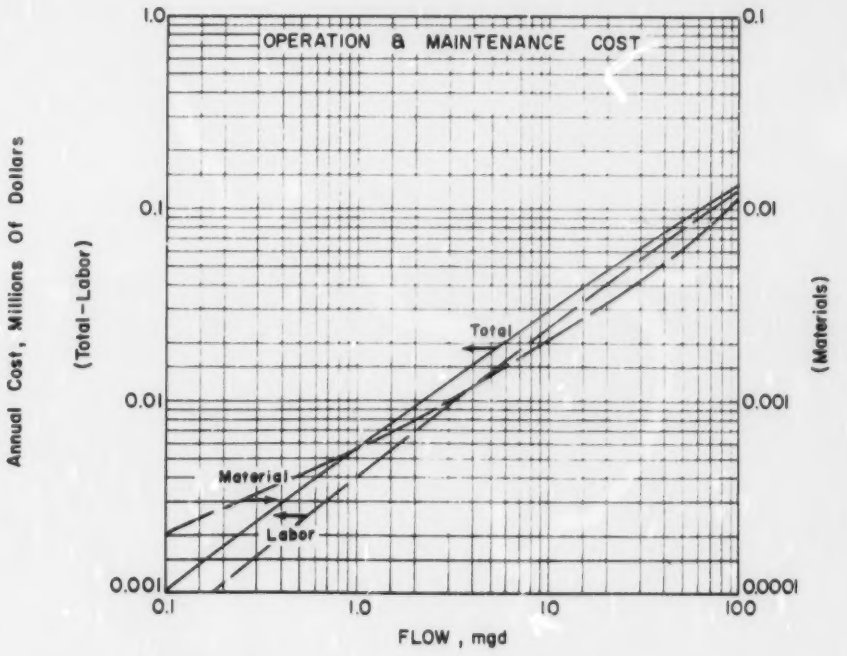
If costs are desired for different application rates enter curve at effective flow (Q_E).

$$Q_E = Q_{DESIGN} \times \frac{\text{10 ton (dry)/acre/yr}}{\text{New Design Application Rate}}$$

Reference: 9

FIGURE H-83 LAND APPLICATION OF SLUDGE





H.8.5 Wastewater Transportation Methods: Cost Curves, Figures H-84 and H-85

FIGURE H-84

GRAVITY SEWERS

Service Life: 50 years

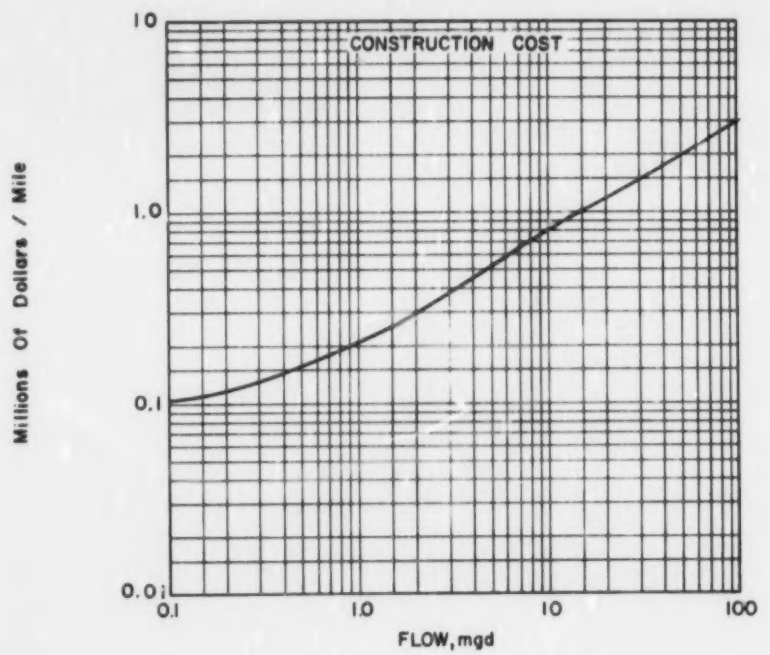
Relative Reliability: Level B

Design Basis:

1. Peaking factor allowance ranges from 3 for flows of 1 mgd and less average flow, to 2 for flows with greater than 10 mgd average flow.
2. Average slope of 0.002 to 0.005.
3. Velocity of not less than 2 fps when flowing full at peak flow; minimum sewer size = 8 inches.
4. Repaving of road surface required for 10% of distance.
5. Does not include right-of-way or aerial crossing, etc.

References: 38, 52

FIGURE H-84 GRAVITY SEWERS



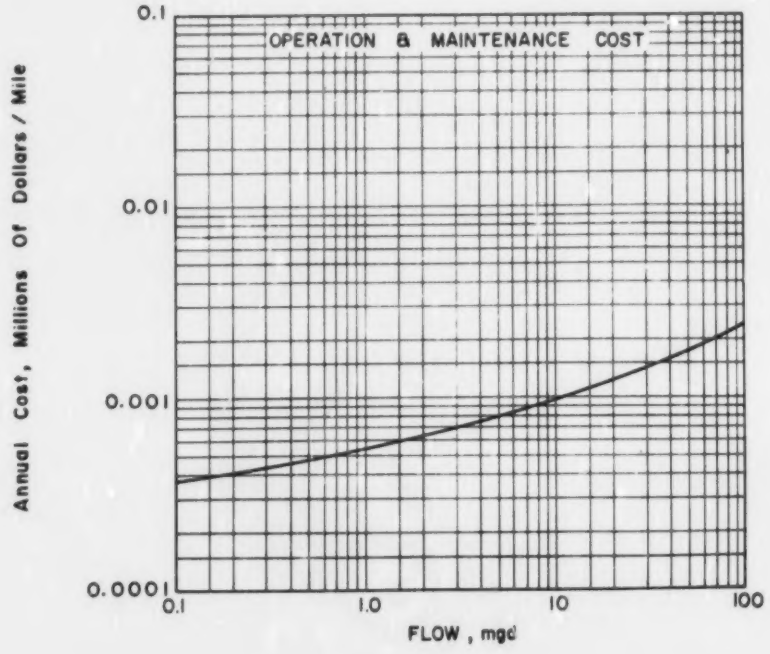


FIGURE H-85

TRANSMISSION FORCE MAIN

Service Life: 50 years

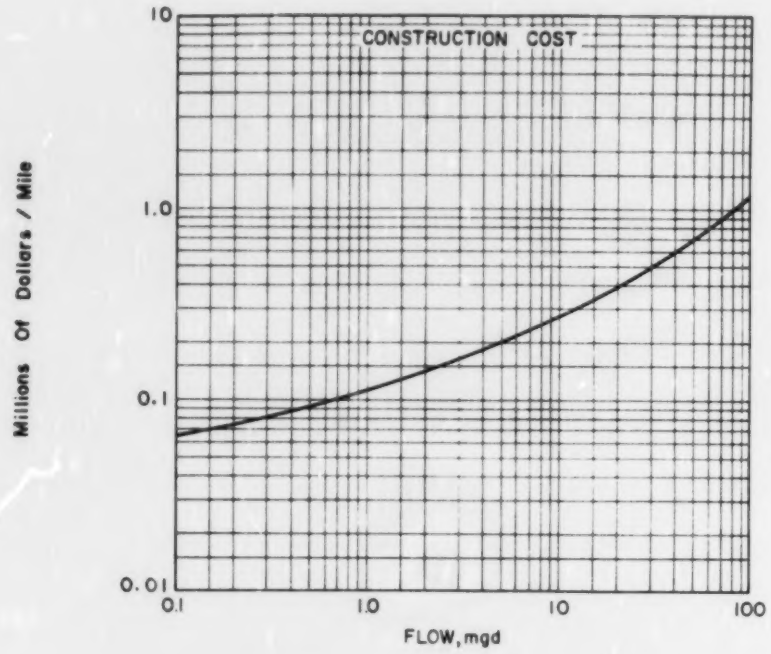
Relative Reliability: Level B

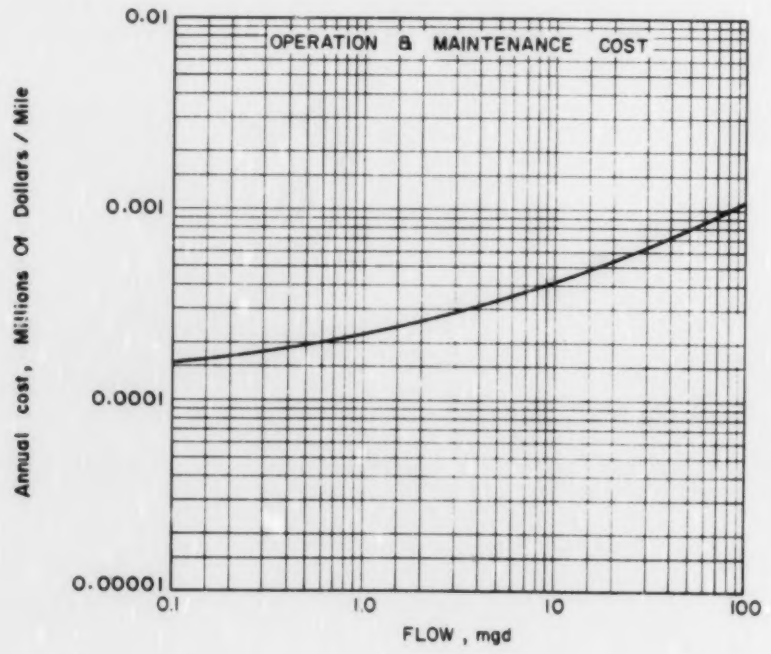
Design Basis:

1. Peaking factor allowance ranges from 3 for flows of 1 mgd and less average flow, to 2 for flows with greater than 10 mgd average flow.
2. 5-ft. depth of cover over crown of pipe.
3. Average velocity of 5 fps.
4. Repaving of road surface required for 10% of distance.
5. Does not include pump stations, right-of-way, aerial crossings, etc.

Reference: 38

FIGURE H-85 TRANSMISSION FORCE MAIN





4.8.6 Sludge Transportation Methods:
Cost Curves, Figures H-86 through H-90

FIGURE H-86

LIQUID SLUDGE TRANSPORT (RAIL)

Service Life: 15 years

Level of Reliability: Level B

Design Basis:

1. Construction cost includes loading facilities.
2. Storage at plant equals one day's production.
3. Pumping and piping are sized to fill 1, 10, 20, and 100 unit car trains in 1.5, 2, 3, and 15 hours, respectively.
4. Rail cars discharge by gravity into unloading storage.
5. Storage at unloading area not included in cost.
6. Travel distances of 40, 80, and 160 miles one way.
7. [illegible] based on 8 hours operation per day.
8. Operation and maintenance costs include car lease, labor, electrical energy, supplies, and rail maintenance.
9. Assume a Full Car Maintenance Lease rate of $525/car.
10. Rail haul charges are based on the following:

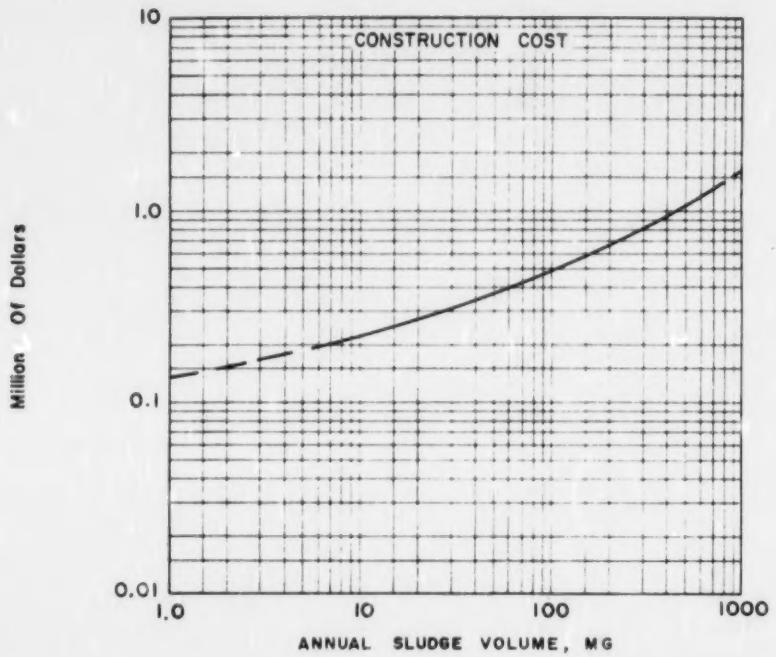
Area	Approximate Railroad Rate Variation, Adjust Accordingly
North Central and Central	Average rate as presented here
Northeast	25% higher than average
Southeast	25% lower than average
Southwest	10% lower than average
West Coast	10% higher than average

The railroads generally allow a rebate of $0.06 to $0.20 per mile per car if the shipper provides the car.

11. Solids content of sludge = 4%.
12. Rail cars have 20,000 gallon capacity.

Reference: 46

FIGURE H-86 LIQUID SLUDGE TRANSPORT (RAIL)



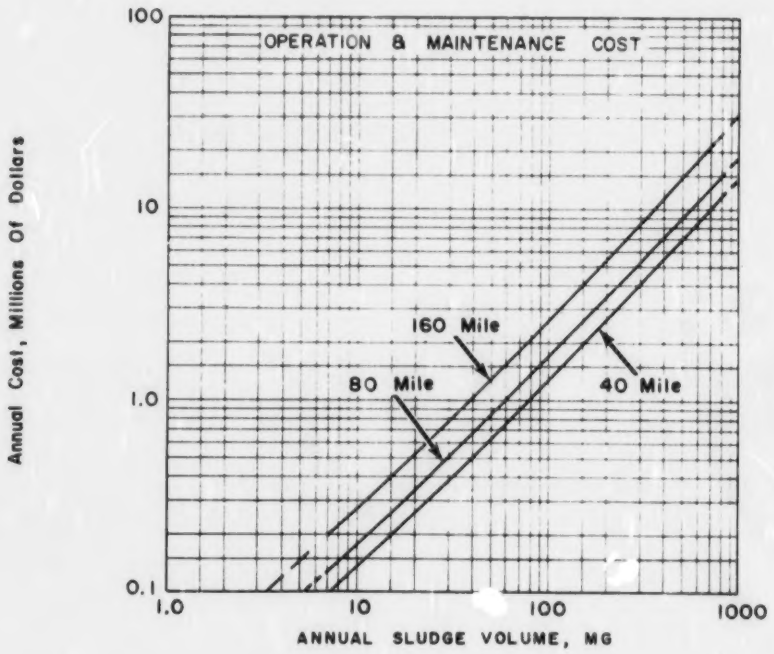


FIGURE H-87

DEWATERED SLUDGE TRANSPORT (RAIL)

Service Life: 15 years

Relative Reliability: Level B

Design Basis:

1. Construction cost includes construction of loading facilities.
2. Loading storage hopper is sized for one car load.
3. Cars are gravity loaded.
4. Rail cars dump by gravity into unloading storage.
5. Storage at unloading area is not included in the cost.
6. Operation and maintenance costs include rail haul charges, labor, electrical power, and supplies for the loading facilities.
7. Assume the railroad provides the hopper cars.
8. Use 50 yd^3 cars for 0-74,000 yd^3 of sludge. Use 100 yd^3 cars for greater than 75,000 yd^3 of sludge.
9. Rail haul charges are based on the following:

Area	Approximate Railroad Rate Variation, Adjust Accordingly
North Central and Central	Average rate as presented here
Northeast	25% higher than average
Southeast	25% lower than average
Southwest	10% lower than average
West Coast	10% higher than average

10. Travel distances presented are 40, 80, or 160 miles one way.
11. Costs based on 8 hours operation per day.

Reference: 46

FIGURE H-87 DEWATERED SLUDGE TRANSPORT (RAIL)

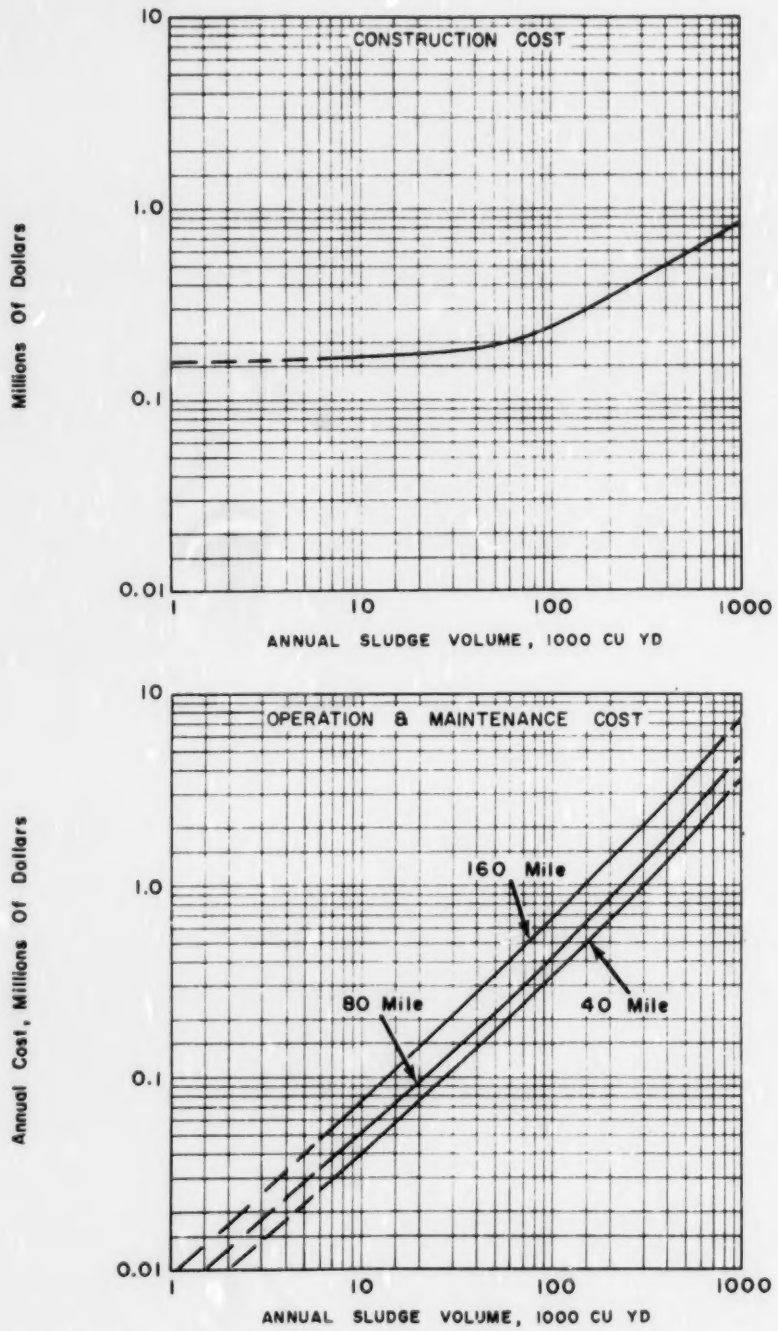


FIGURE H-88

DEWATERED SLUDGE TRANSPORT (TRUCK)

Service Life: 15 years

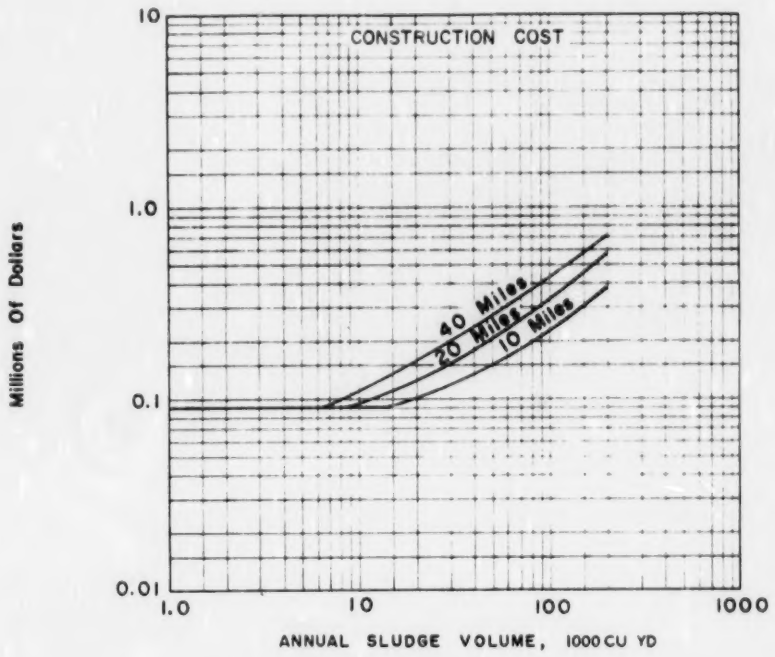
Level of Reliability: Level B

Design Basis:

1. Construction cost includes truck purchase and load/unload facilities.
2. Operation and maintenance costs include truck maintenance, truck operation and fuel, labor for truck and loading facility operation, electrical power, and supplies for the loading facility.
3. Costs are based on use of most cost effective size trucks per volume of sludge transported. Truck sizes are 10 yd^3 and 30 yd^3.
4. Loading hopper is sized for one truck.
5. Equipment is sized to fill truck in 20 minutes maximum.
6. Loading into truck is by gravity. Truck unloading at disposal sites is also by gravity.
7. Storage at unloading site is not included in cost.
8. Costs are based on 8 hours operation per day for 360 days per year.
9. Travel distances of 10, 20, or 40 miles one way to disposal site.
10. Dewatered sludge cake solid content: 25%

Reference: 46

FIGURE H-88 DEWATERED SLUDGE TRANSPORT (TRUCK)



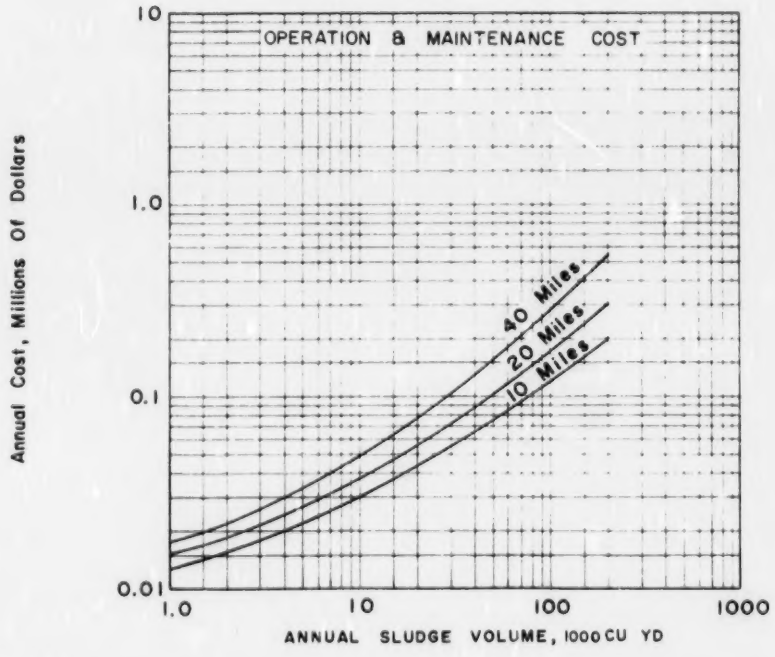


FIGURE H-89

LIQUID SLUDGE TRANSPORT (TRUCK)

Service Life: 15 years

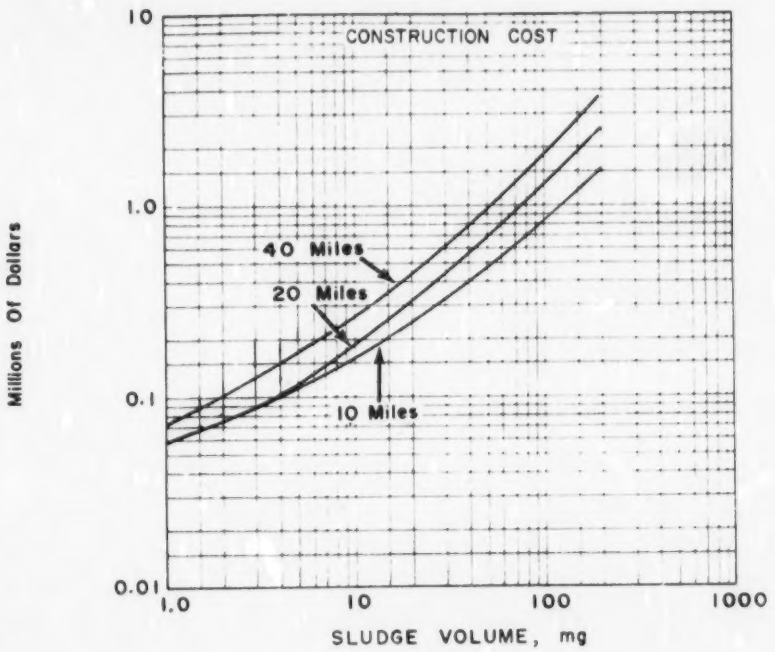
Level of Reliability: Level B

Design Basis:

1. Construction costs include truck purchase and load/unload facilities.
2. Operation and maintenance costs include truck maintenance, truck operation and fuel, labor for truck and loading facility operation, electrical power, and supplies for the loading facility.
3. Costs are based on use of most cost effective size trucks per volume of sludge transported. Truck sizes are 1200 gallon, 2500 gallon, and 5500 gallon.
4. Equipment is sized to fill truck in 20 minutes maximum.
5. Loading into truck is by gravity. Truck unloading at disposal site is also by gravity.
6. Storage at unloading site is not included in cost.
7. Costs are based on 8 hours operation per day for 360 days per year.
8. Travel distances of 10, 20, or 40 miles one way to disposal site.
9. Fuel cost (gasoline) = $0.60/gallon.
10. Liquid sludge = 4% solids.

Reference: 46

FIGURE H-89 LIQUID SLUDGE TRANSPORT (TRUCK)



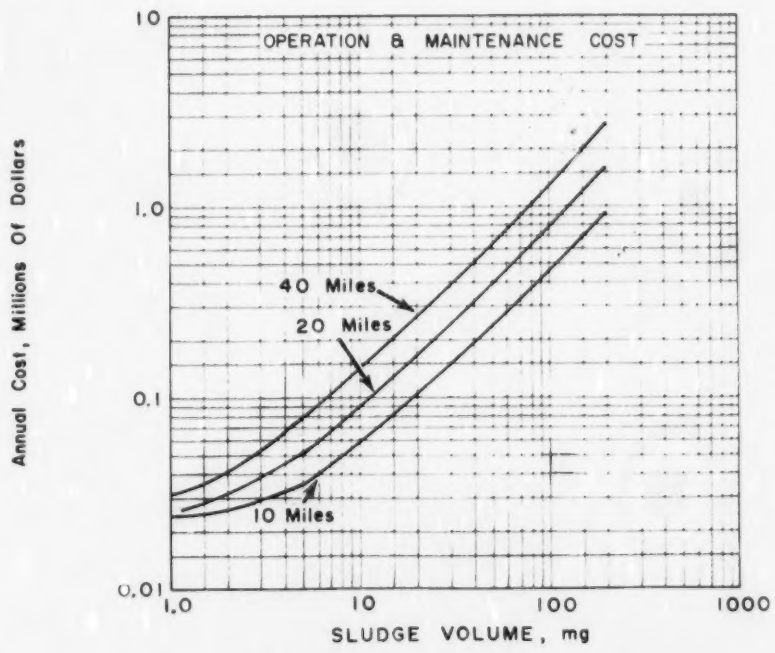


FIGURE H-90

SLUDGE TRANSPORT (PIPELINE)

Service Life: 15 years

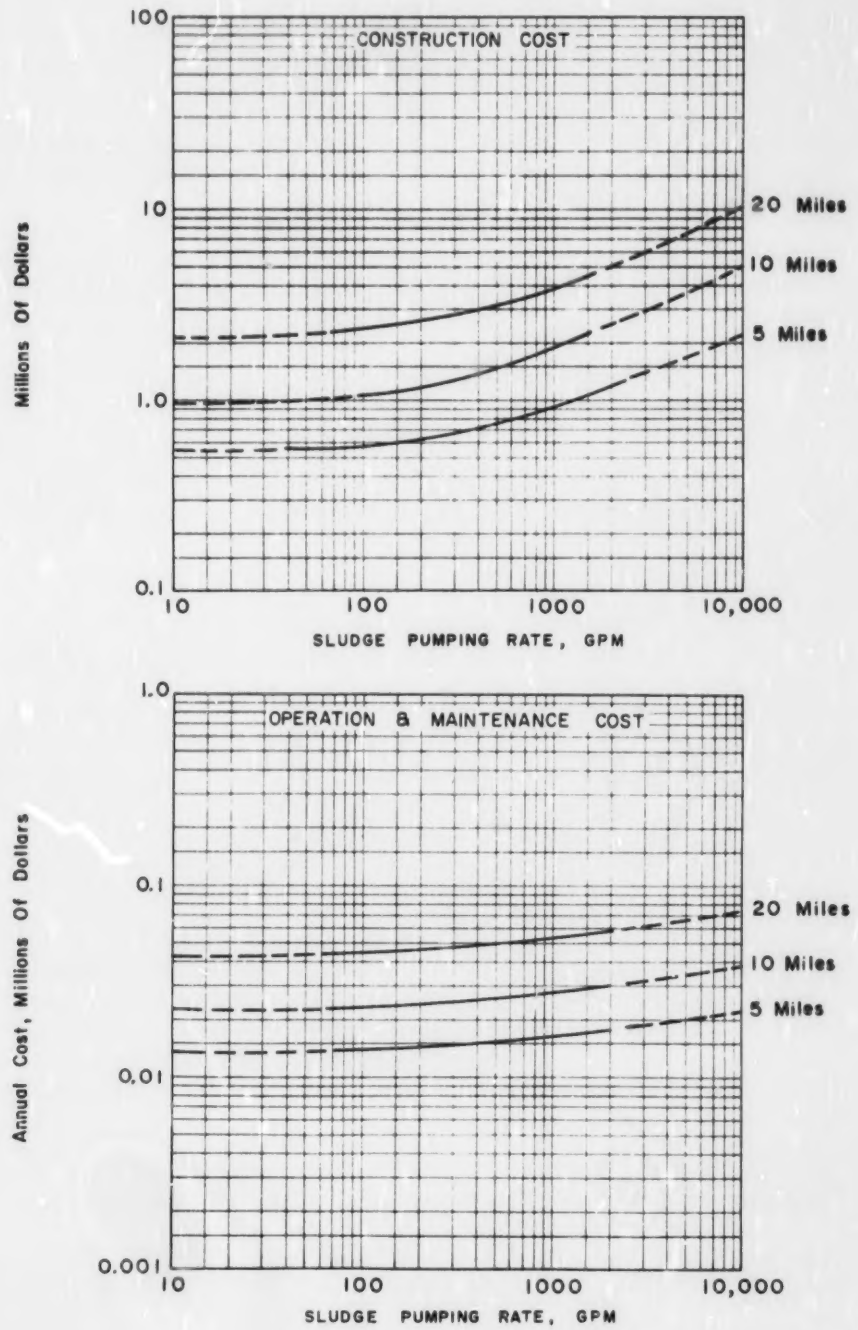
Relative Reliability: Level B

Design Basis:

1. Construction cost includes: pipeline and pumping stations. Cost includes one major highway crossing per mile, one single rail crossing per 5 miles, and a nominal number of driveways and minor road crossings.
2. Flow velocity = 4.0 fps.
3. Pumping distances of 5, 10, and 20 miles.
4. No rock excavation or major unusual problems (for hard rock add 70% to cost).
5. Pipeline is buried 3 to 6 feet. For 6-10 feet, add 15% to cost.
6. No elevation change in pipeline.
7. Minimum pipe size is 4 inches.
8. Pipeline is cement-lined cast iron or ductile iron.
9. Costs based on 12 hours pumping per day.
10. Operation and maintenance cost includes labor, supplies and electrical power for pump stations.
11. Pumps are dry-pit, horizontal or vertical, non-clog centrifugal pumps operating at 1780 rpm.

Reference: 46

FIGURE H-90 SLUDGE TRANSPORT (PIPELINE)



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CINCINNATI, OHIO 45268

TO: Users of the Areawide Assessment Procedures Manual

The attached text and Volume III AAPM binder constitutes the third of three mailings of the Areawide Assessment Procedures Manual. The titles of the five sections which are included, and the correct placement of each in the now completed three-volume set is described as follows:

Volume	Index Tab Notation	Text Title
I	Evaluation and Selection of Control Alternatives	Chapter 6 - Evaluation and Selection of Control Alternatives
II	Monitoring	Appendix D, Part II - Parameter Handbook
III	Best Management Practices	Appendix G, Parts I and II - Urban Stormwater Management Techniques: Performance and Costs
III		Appendix H - Point Source Control Alternatives: Performance and Cost
II	Bibliography	Appendix I - Bibliography

These sections of the manual are to be inserted into their correct places in the binders which have been received previously or in the Volume III binder which is attached.

The distribution of the third mailing of the manual is being made to those individuals, agencies, and/or companies who received the first and second mailings on a priority basis as well as to those individuals, etc. who have requested it.

As was stated previously by memo with the first and second mailings, there is a necessity to complete and return the manual registration form, EPA-291, which was included with the text of the first mailing. Those who fill in the form and return it per the instruction are registered as recipients of the manual and will receive automatically future manual updates and additions.

The receipt of this (third) mailing marks the completion of the first edition of the Areawide Assessment Procedures Manual. However, the dynamics of research

will continue to increment our knowledge and advance the technologies of water quality planning and control, and new developments will permit the implementation of advanced management and treatment techniques. As the state of the art is expanded with greater definition, research results will be published as additions to or revisions of the first edition of the AAPM. In this way the newest information which becomes available from research efforts can be applied in a practical manner to the planning and decision-making process and can impact in a positive way the approach to an optimal solution to the preservation or improvement of water quality.

APPENDIX I

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Areawide Assessment Procedures Manual
Chapter 6
Evaluation and Selection
of Control Alternatives

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CHAPTER 6

EVALUATION AND SELECTION OF CONTROL ALTERNATIVES

6.1 Introduction

Chapter 6 provides an approach for developing cost-effective water quality management plans for the 208 planning area. This chapter extends the analysis procedures of Chapter 5 by presenting guidance for establishing water quality objectives, for developing strategies for waste load reductions and allocations, and for developing and evaluating alternatives for controlling pollutant sources. The discussion presented in this chapter is intended to provide guidance for these activities. However, where other techniques for load reduction or cost optimization are available to the 208 planner or engineer, they may be substituted in whole or in part for the methods presented in Chapter 6.

Water quality objectives are defined from consideration of water quality standards and water use objectives within the 208 planning area. For certain parameters, it will be difficult to meet desired water quality objectives through urban source controls because of the contribution of upstream non-point source loadings, both within and outside ("background") the 208 planning area. In such cases, the 208 planner will have to investigate combinations of urban and non-point source control practices which achieve water quality objectives.

Techniques for developing rational load-reduction strategies in the 208 planning area are presented. These include controls for both dry- and wet-weather water quality problems, through combinations of municipal and industrial point source controls and storm water controls. Methods are presented for determining the levels of control required at each source in order to attain the relevant water quality objectives.

A methodology is provided for developing and evaluating methods for controlling individual pollutant sources in a 208 planning area. For purposes of this manual, these methods will be referred to as control alternatives. Examples of control alternatives are: an upgraded wastewater treatment plant

to handle a point source problem; a storage basin and treatment unit to reduce loadings from combined sewer overflows; and a street-sweeping program to reduce runoff loadings from urbanized areas. (Although not discussed in detail, control techniques for non-urban sources are mentioned in Chapter 4.)

In developing methods of control for wastewater sources, the capability of various control alternatives to achieve specified performance requirements is considered. Performance requirements are stated in terms of percentage reductions of wastewater source loadings necessary to achieve the identified water quality objectives for the receiving water. Alternative combinations of percentage load reductions from the various sources are developed through the water quality impact analysis procedures in Chapter 5. These alternative combinations are referred to as load-reduction strategies. Control alternatives which meet the performance requirements stated in the load-reduction strategies are then evaluated to determine the monetary cost of implementing the alternatives.

The monetary cost of control alternatives is only one of the factors upon which a final selection of an alternative is based. Other important factors include: technical reliability; economic, social and environmental impact; implementation feasibility; and public acceptability. In this manual, however, the evaluation of alternatives is based only on monetary cost; the other considerations, and the final selection of control alternatives, are beyond the scope of this manual. Other EPA 208 guidance documents address the consideration of other factors needed to determine the control alternatives most desirable from an economic, environmental, and social point of view.

6.2 Water Quality Objectives

Water quality standards are the water quality objectives most frequently utilized in wastewater management programs. State agencies establish standards to satisfy State and Federal water quality objectives. These standards are generally based on scientific or empirical evidence that indicate enhancement of water uses when water quality is within prescribed limits. Information regarding local water quality standards can be ob-

tained from the State water quality agencies listed in Table 2-7 (pg. 2-43).

Standards are established to achieve objectives which include but are not limited to:

1. Protection of public health where waters are to be used for recreation, public water supply, or commercial harvesting of fin and shell fish.
2. Protection of the integrity and diversity of the aquatic and marine biology, including valuable commercial and sport fisheries.
3. Insurance of safety to recreational and commercial navigation.
4. Protection of industrial and agricultural water supply.
5. Maintenance of publicly acceptable levels of aesthetic water quality.

In general, the 208 planner should consider water quality standards specific to the planning area as the minimum acceptable water quality objectives.

In certain cases, there are no water quality standards for variables which are at problem levels in a specific study area. For example, local standards might not prescribe maximum levels of nitrogen and phosphorus to protect against nuisance algal blooms. In these instances, the 208 planner should develop target levels of water quality parameters that will insure a desirable level of water quality protection in the study area.

One basis for defining water quality objectives not specifically dealt with in existing standards is contained in Chapter 2 -- Tables 2-22 (pg. 2-100), 2-23 (pg. 2-104), 2-24 (pg. 2-107), and 2-25 (pg. 2-111). These tables, however, are presented for guidance purposes only and should be modified to reflect local experience. Additional information which will prove to be valuable in setting water quality objectives in the absence of specific standards is contained in reference (1).

Finally, there will be cases where water quality contravenes standards or other water quality objectives are attributable to upstream effects which are either outside of the planning agencies jurisdiction or are uncontrollable using present technology. These cases should be addressed by assigning

reasonable objectives which involve consideration of opportunities to meet water quality goals at some future time if upstream controls can be implemented, and which recognize the practical water use benefits of partial control of existing problems.

6.3 Load-Reduction Analysis

An overall aim of water quality analysis in a 208 plan is to describe waste-load reductions which result in compliance with water quality objectives. This aim is achieved through a waste-load allocation analysis which specifies alternative combinations of allowable loads to satisfy water quality objectives. This section provides a methodology for development of the required load-reduction strategies.

The procedure for identifying the needs for water quality improvement (outlined in Figure 6-1) summarizes many of the analyses made in Chapter 5 and provides the receiving-water-oriented basis for making allocations for waste-load reduction. The methods of Chapters 2, 3, and 5 normally precede the load-reduction strategy. In particular, the analysis methods of Chapter 2 provide an initial assessment of water quality problems and their associated loads. More detailed loads are then generated in Chapter 3 and applied in detailed water quality analyses using methods presented in Chapter 5. Chapter 6 then provides a systematic approach to developing load-reduction strategies to achieve water quality objectives. The methodology is described briefly as follows.

Projections are developed for each relevant water quality constituent for selected river-flow conditions (Section 2.7, pg. 2-97). The summer low flow (normally described by the 7-consecutive-day/once-in-ten-year low flow) is usually considered the critical case for analyzing dissolved oxygen concentrations, as well as nutrients and other point source pollutants from municipal and industrial sources, and should be examined first (Section 2.7.1.3, pg. 2-101). Storm-related problems are then examined during mean or design-storm conditions (Section 2.7.1.2, pg. 2-101). Pollutants which have longer-term impacts are analyzed on a long-term average basis (Section 2.7.3, pg. 2-107).

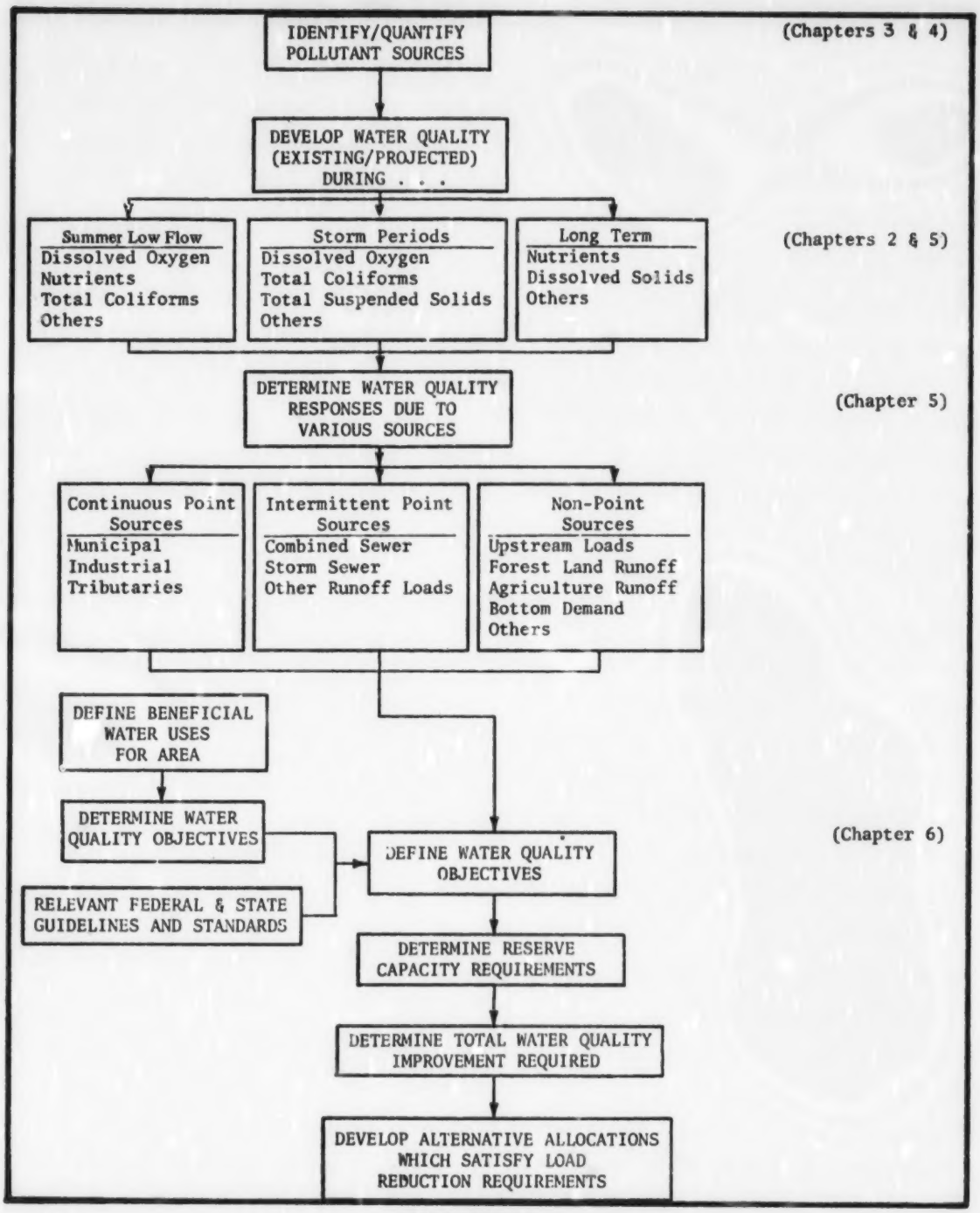


FIGURE 6-1
PROCEDURE FOR DETERMINING WATER QUALITY IMPROVEMENT REQUIREMENTS

Each of these analyses is employed in identifying water quality impacts of the waste loads at critical locations in the stream. The results are then used in determining the degree to which present and projected loads contribute to water quality problems, and, furthermore, the degree of load reduction required to meet water quality goals. The final element of the allocation analysis is a stepwise procedure which develops acceptable load-reduction strategies.

Various water quality problems in the hypothetical South River are identified and analyzed in Chapter 5. In Chapter 6, combinations of point source, urban non-point source, storm sewer and combined sewer load reductions necessary to meet water quality objectives are identified, and control alternatives to improve water quality to desired levels are analyzed.

6.3.1 Sample Problem

The objectives used for the hypothetical South River are presented in Table 6-1. Water quality standards set the objective levels for dissolved oxygen, while objectives for other variables are defined in the 208 planning process from consideration of background water quality and site-specific water uses. The Dissolved Oxygen (D.O.) standard indicates that the D.O. concentration should be above 5 mg/l from M.P. 0 to M.P. 20, and above 4 mg/l from M.P. 20 to M.P. 35. To evaluate this objective effectively, analyses are demonstrated in Chapter 5 for low-flow conditions and for conditions during the "average" storm. Figures 5-10 (pg. 5-41) and 5-11 (pg. 5-42) indicate that the D.O. standards are currently violated under these conditions.

Water quality objectives are also developed for total coliform organisms, total suspended solids, total nitrogen, and total phosphorus. The objectives may still result in problematic conditions, but they appear to be reasonable as initial objectives due to the current level of pollutants from upstream non-point and background sources. The objectives for total coliform organisms and for total suspended solids are defined in terms of the concentration during the average storm, while the objectives for nitrogen and phosphorus are defined in terms of the average (long-term) summer concentration (including storm and non-storm periods) because of the longer

TABLE 6-1

SOUTH RIVER
DISSOLVED OXYGEN OBJECTIVES

1.	Dissolved Oxygen - 1 (DO-1)	Dissolved oxygen minimum of 5 mg/1 from MP 0 to MP 20 and Dissolved Oxygen minimum of 4 mg/1 from MP 20 to MP 35 during 7 day-10 year low flow
	Dissolved Oxygen - 2 (DO-2)	Dissolved oxygen of 5 mg/1 from MP 20 and Dissolved oxygen minimum of 4 mg/1 from MP 20 to MP 35 during mean storm.

Goals For Other Water Quality Variables

2.	Total Coliform Organisms - 1 (TC-1)	Total Coliform Organisms not to exceed 5,000 MPN/100 ml during mean storm
	Total Suspended Solids - 1 (TSS-1)	Total suspended solids not to exceed 200 mg/1 during mean storm
	Nitrogen - 1 (N-1)	Average total Nitrogen not to exceed 2.5 mg/1 as a long term summer average
	Phosphorus - 1 (P-1)	Average total Phosphorus not to exceed 0.4 mg/1 as a long term summer average

temporal scale of impacts associated with nutrients. The rationale for describing these as critical time periods for each water quality variable are described in Chapter 2 and summarized in Chapter 5 (pg. 5-43).

The water quality constituents of concern in the hypothetical South River and the locations of the maximum concentrations are summarized in Table 6-2. Preliminary estimates of the load reductions required to meet water quality objectives at these locations are also summarized in Table 6-2. In this regard, the contributions to water quality problems attributable to each source and the total reductions required to meet the water quality objectives are estimated in Table 6-2.

Using this data, the allocation proceeds through the steps outlined in Figure 6-2. Section (a) of the diagram describes the procedures for developing waste-load allocations for dry-weather conditions, and section (b) describes the procedures for wet-weather conditions. The steps in this dry-weather allocation analysis are described and illustrated sequentially in the following paragraphs.

6.3.2 Dry-Weather Allocation Analysis

Figure 5-11(a) (pg. 5-42) indicates two critical locations at which Dissolved Oxygen concentration is in violation of water quality standards: Milepoints 19.5 and 23.5. The unit response presented in Figure 5-11(b) suggests that one alternative which could satisfy the water quality standards while maintaining a reserve of 0.5 mg/l of Dissolved Oxygen at the critical location is treatment at STP #2 alone. This conclusion is developed as follows:

Critical deficit at M.P. 23.5:	8.1 mg/l
Allowable deficit at M.P. 23.5:	8.17 mg/l (saturation)
	-4.00 mg/l (standard)
	4.17 mg/l
	-0.50 mg/l (reserve)
	3.67 mg/l (allowable)

TABLE 6-2

HYPOTHETICAL SOUTH RIVER WATER QUALITY SUMMARY (20 YEAR PROJECTIONS)

Constituent:	Dissolved Oxygen Deficit			Total Coliform	Total Suspended Solids	Total Nitrogen	Total Phosphorus
Flow Condition:	Low Flow	Low Flow	Mean Summer Flow	Mean Summer Flow	Mean Summer Flow	Average Summer Flow	Average Summer Flow
Location of Peak Concentration (Milepoint)	19.5 (Critical Location in Upper Reach)	23 (Critical Location in Lower Reach)	33	19	15	24	24
Components of Impact at Critical Location	(mg/l)	(mg/l)	(mg/l)	MPN/100 ml	(mg/l)	(mg-N/l)	(mg-P/l)
a) STP I	-	3.10	0.55	-	-	0.90	0.45
b) STP II	5.25	5.00	1.00	350	-	1.60	0.80
c) Industry	-	-	0.15	-	-	-	-
d) Storm Sewer Runoff	-	-	1.10	53,000	260	-	-
e) Combined Sewer Overflow	-	-	2.00	1,150,000	-	-	-
f) Other Background Loads	0.05	0.05	0.50	330	110	1.45	0.15
g) Total	5.30	8.15	5.30	1,204,000	370	3.95	1.40
Criteria/Objective	DO=5 C_s=8.17 Allowable DEF=3.17	DO=4.0 C_s=8.17 Allowable DEF=4.17	DO=4.00 C_s=8.17 Allowable DEF=4.17	5,000	200	2.50	0.40
Preliminary Estimate of Required Reduction	$\frac{2.13 + 0.50 \text{(Reserve)}}{2.63}$ $\frac{2.63}{5.30}$ = 50%	$\frac{3.98 + 0.50 \text{(Reserve)}}{4.48}$ $\frac{4.48}{8.15}$ = 45%	$\frac{1.13 + 0.50 \text{(Reserve)}}{1.63}$ $\frac{1.63}{5.30}$ = 31%	1,199,000 (99.6%)	170 (46%)	1.45 (37%)	1.90 (72%)

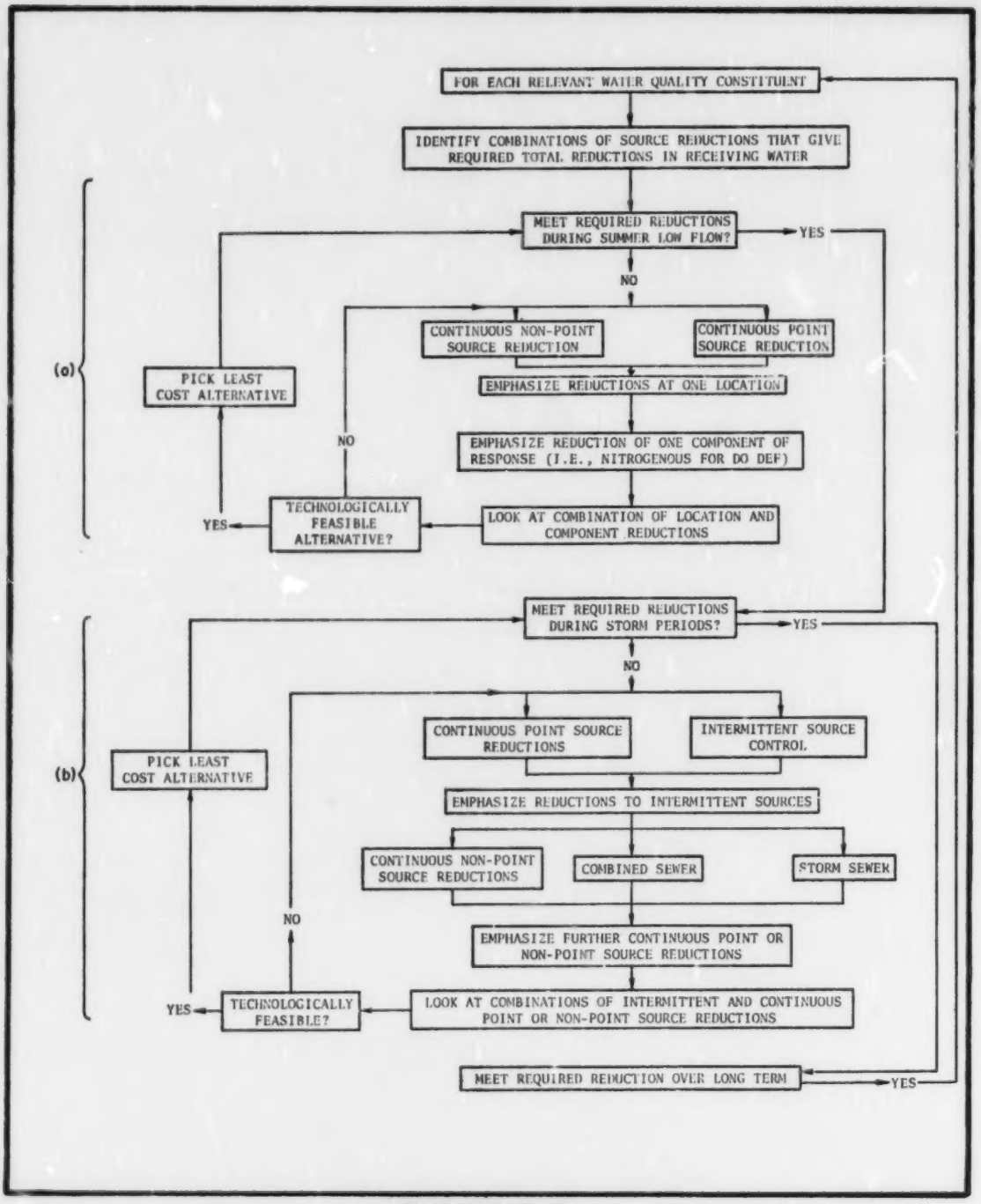

FOR EACH RELEVANT WATER QUALITY CONSTITUENT
IDENTIFY COMBINATIONS OF SOURCE REDUCTIONS THAT GIVE REQUIRED TOTAL REDUCTIONS IN RECEIVING WATER
MEET REQUIRED REDUCTIONS DURING SUMMER LOW FLOW?
YES
NO
(a)
CONTINUOUS NON-POINT SOURCE REDUCTION
CONTINUOUS POINT SOURCE REDUCTION
EMPHASIZE REDUCTIONS AT ONE LOCATION
EMPHASIZE REDUCTION OF ONE COMPONENT OF RESPONSE (I.E., NITROGENOUS FOR DO DEF)
LOOK AT COMBINATION OF LOCATION AND COMPONENT REDUCTIONS
TECHNOLOGICALLY FEASIBLE ALTERNATIVE?
NO
YES
PICK LEAST COST ALTERNATIVE
MEET REQUIRED REDUCTIONS DURING STORM PERIODS?
YES
NO
(b)
CONTINUOUS POINT SOURCE REDUCTIONS
INTERMITTENT SOURCE CONTROL
EMPHASIZE REDUCTIONS TO INTERMITTENT SOURCES
CONTINUOUS NON-POINT SOURCE REDUCTIONS
COMBINED SEWER
STORM SEWER
EMPHASIZE FURTHER CONTINUOUS POINT OR NON-POINT SOURCE REDUCTIONS
LOOK AT COMBINATIONS OF INTERMITTENT AND CONTINUOUS POINT OR NON-POINT SOURCE REDUCTIONS
TECHNOLOGICALLY FEASIBLE?
NO
YES
PICK LEAST COST ALTERNATIVE
MEET REQUIRED REDUCTION OVER LONG TERM
YES

FIGURE 6-2
METHODOLOGY FOR DETERMINING
LOAD REDUCTION REQUIREMENTS

The total deficit due to STP #1 and the industry is 3.3 mg/1 at Milepoint 23.5. Thus the allowable deficit due to STP #2 at Milepoint 23.5 is:

Allowable Total Deficit (M.P. 23.5)	3.67 mg/1
Deficit (other sources)	3.30 mg/1
Allowable STP #2 deficit (M.P. 23.5	0.37 mg/1

Thus if the deficit from the STP #2 discharge can be reduced to 0.37 mg/1, the D.O. water quality standards can be maintained. The required additional UOD (Ultimate Oxygen Demand) reduction in the secondary effluent is computed as follows:

Deficit due to STP #2 (M.P. 23.5)	8.10 mg/1 (total deficit)
	3.10 mg/1 (STP #1 Deficit)
	5.00 mg/1 (STP #2 Deficit)

Present reduction required = $\frac{5.00-0.37}{5.00}$ = 92.6 percent UOD removal

The required reduction must be accomplished through a combination of carbonaceous and nitrogenous BOD removal which satisfies the 92.6 percent UOD reduction criteria.

Clearly, other combinations of treatment at STP #1 and STP #2 can also be considered. For example, the minimum treatment above secondary treatment at STP #2 which satisfies the water quality standards considers reduction in the UOD load at that plant such that compliance with the standard is achieved at Milepoint 19.5 (the critical point in the STP #2 D.O. deficit profile). The computation proceeds as follows:

Total deficit at M.P. 19.5	5.3 mg/1
Allowable deficit at M.P. 19.5	8.17 mg/1 (saturation)
	-5.00 mg/1 (standard)
	3.17 mg/1
	-0.50 mg/1 (reserve)
	2.67 mg/1 (allowable)

The percent UOD reduction is computed as:

Total deficit due to STP #2 (M.P. 19.5)	5.3 mg/1

Percent reduction required = $\frac{2.67}{5.30}$ = 50 percent UOD removal

Therefore, the minimum additional treatment of the secondary discharge required at STP #2 is 50 percent reduction of UOD, which can be accomplished through various combinations of carbonaceous and nitrogenous BOD removal. The resulting D.O. profile in the South River is illustrated in Figure 6-3. The figure indicates the need for additional removals of UOD at STP #2. Computation of this load reduction is accomplished as follows:

Deficit due to STP #1 (M.P. 23.5)	3.3 mg/l
Allowable deficit at M.P. 23.5	8.17 mg/l (saturation)
	-4.00 mg/l (standard)
	4.17 mg/l
	-0.50 mg/l (reserve)
	3.67 mg/l (allowable)

A 50 percent reduction in UOD at STP #2 reduces the deficit due to STP #2 at Milepoint 23.5 from 4.1 mg/l to 2.05 mg/l (0.5 x 4.1 = 2.05). The total deficit at M.P. 23.5 is calculated to be:

Deficit due to STP #1 (M.P. 23.5)	3.30 mg/l (Figure 5-10)
Deficit due to STP #2 (M.P. 23.5)	2.05 mg/l (above)
Total deficit (M.P. 23.5)	5.35 mg/l

and the load reduction at STP #1 is:

Total deficit (M.P. 23.5)	5.35 mg/l
Allowable deficit (M.P. 23.5	3.67 mg/l
Difference	1.68 mg/l
Percent reduction at STP #1	1.68 = 51% UOD removal
	3.30

The resulting D.O. profile based on 50 percent UOD removal at STP #2 and 51 percent UOD removal at STP #1 is shown in Figure 6-3. Note that the final allocation results in a 0.5 mg/l reserve to allow for modeling uncertainties and for future growth. The selection of a reserve capacity is normally based on a local knowledge of future growth projections and on an understanding of uncertainties in the water quality modeling framework. A reserve of 0.5-1.0 mg/l is typical.

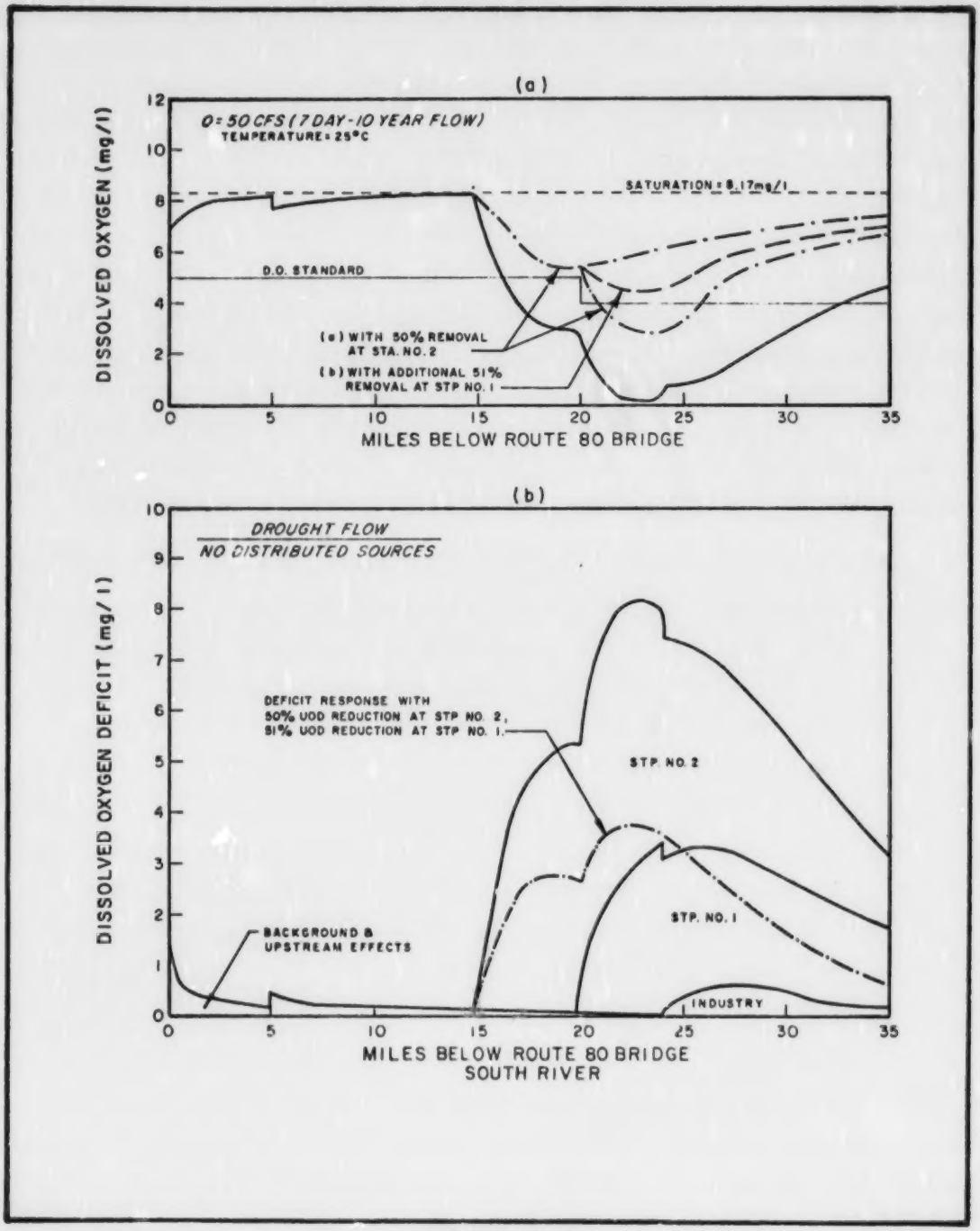

(a)
Q=50 CFS (7 DAY-10 YEAR FLOW)
TEMPERATURE=25°C
SATURATION=8.17mg/l
D.O. STANDARD
(a) WITH 50% REMOVAL AT STA. NO. 2
(b) WITH ADDITIONAL 51% REMOVAL AT STP NO. 1
DISSOLVED OXYGEN (mg/l)
MILES BELOW ROUTE 80 BRIDGE
(b)
DROUGHT FLOW
NO DISTRIBUTED SOURCES
DEFICIT RESPONSE WITH 50% UOD REDUCTION AT STP NO. 2, 51% UOD REDUCTION AT STP NO. 1.
STP NO. 2
STP NO. 1
INDUSTRY
BACKGROUND & UPSTREAM EFFECTS
DISSOLVED OXYGEN DEFICIT (mg/l)
MILES BELOW ROUTE 80 BRIDGE
SOUTH RIVER

FIGURE 6-3
EFFECT OF WASTE LOAD REDUCTION ON DRY WEATHER DISSOLVED OXYGEN CONCENTRATION

The user should be aware that EPA guidelines do not provide specific recommendations for how much reserve capacity (if any) should be included in wasteload allocation for future growth (whether for possible industrial activities whose wastewaters will not be treated by municipal facilities or for "ultimate development"). In many cases, there will be strong pressure for full utilization of stream assimilative capacity in order to hold down treatment costs. In stream segments where assimilative capacity is already or expected to be constrained during the planning period, local communities will be faced with difficult wasteload allocation decisions. Such decisions should be supported by local growth policies, other local policies, and related regulatory programs (i.e., local ordinances and pricing structures designed to encourage flow reduction or pretreatment). While discussion of these non-structural management techniques is beyond the scope of this manual, the user should be cognizant of their potential application.

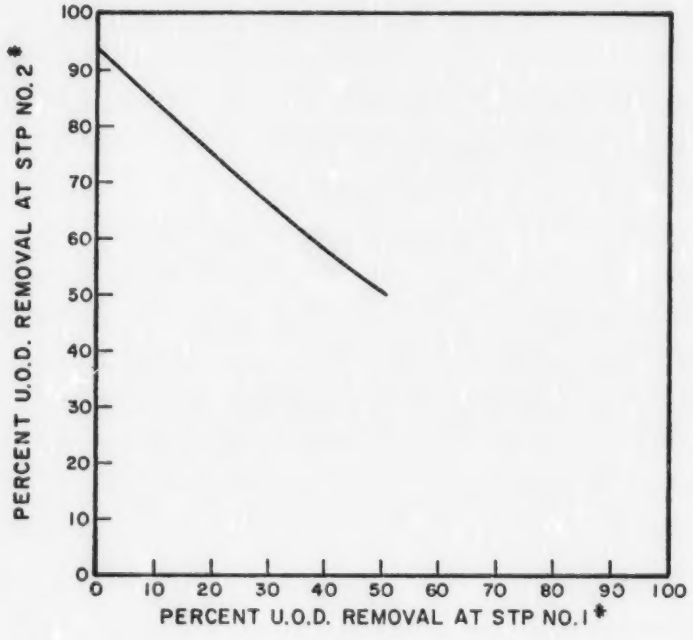
The conclusions that can be drawn from the analysis to this point are:

1. Compliance with D.O. water quality standards during critical-flow, dry-weather conditions requires treatment at least at STP #2. The upper limit on that treatment is an additional 92.6 percent UOD removal. The lower limit on treatment at STP #2 requires an additional 50 percent UOD removal at STP #2 and an additional 51 percent UOD removal at STP #1.

2. There is a continuum of allocations which can be developed for both plants to attain additional UOD reductions of between 50 percent and 92.6 percent at STP #2 and between 51 percent and 0 percent at STP #1.

3. Additional UOD load reductions at either plant can be accomplished through carbonaceous and/or nitrogenous removal.

At this point, the analyst is faced with the problem of determining the most cost-effective treatment option which effects compliance with water quality objectives. A convenient way of viewing the options is presented in Figure 6-4, which displays combinations of UOD removals at the two treatment plants which result in satisfactory water quality. For example, 75 percent UOD removal at STP #2 and 20 percent removal at STP #1 also results in compliance



NOTE:
* PERCENT UOD REDUCTIONS REPRESENT ADDITIONAL REDUCTIONS BEYOND PRESENT TREATMENT.

FIGURE 6-4
ALTERNATIVE ALLOCATIONS AT TWO POINT SOURCES
HYPOTHETICAL SOUTH RIVER EXAMPLE

with the water quality standards under critical-flow, dry-weather conditions. The relationship in Figure 6-4 is not necessarily linear and must be determined by computing several independent allocations. Also, this formulation is not appropriate where the carbonaceous and nitrogenous BOD decay rates are significantly different. Similar allocation procedures apply to other water quality variables which contribute to dry-weather water quality problems.

6.3.3 Wet-Weather Load Reductions

Once the dry weather allocations have been completed for each of those water quality parameters for which problems are projected to exist, the analysis proceeds to wet-weather load allocations. The specific techniques presented here are limited to wet-weather allocations based on treatment of a design-storm load only. The reason for this restriction is that the state-of-the-art technology regarding the effect of storm-water-control structures on the statistical properties of the storm load (probability density function and coefficient of variation) is limited at present to statements regarding the mean load from the control device. As more information regarding the behavior of these devices is developed from prototype units, present theories regarding the relationships between the input and output storm-load statistics of control devices may be verified or modified such that full characterization of the frequency distribution of treated storm loads can be made.

In practical terms, this places limitations on the use of a statistical approach for wet-weather allocations until additional information on the behavior of storm treatment and control devices becomes available, as previously described. To further illustrate this limitation, consider Figure 5-10 (pg.5-41). The figure shows that the mean storm results in a minimum D.O. deficit of 2.8 mg/l at Milepoint 34; the standard is 4.0 mg/l at this point. Therefore, the load reduction developed in this section considers treatment of the mean load such that the minimum D.O. concentration during the mean storm is raised from 2.8 mg/l to 4.0 mg/l. Since further evaluations using the probability density function or the variability of the treated load cannot be made, the frequency distribution of water quality for treated loads cannot be defined as it was for untreated loads in Chapter 5.

It should be noted, however, that if one knows the probability density function and the variability (coefficient of variation) of the treated load, the frequency distribution of water quality responses due to treated loads could be calculated in exactly the same manner as presented in Chapter 5 for untreated storm loads. Two ways to overcome this problem are under development. First, theoretical studies of treatment-device effect on the probability density function, and of variability around a treated mean storm load are now in the research stage, and possibly will be developed for application purposes within a year or two. Second, the statistical properties of the treated storm load may be empirically determined through the use of treatment-device simulators on a long sequence of treated storm loads.

The output from such studies can be used to develop the statistics of treated storm water loads for inclusion in a water quality analysis such as that presented in Chapter 5. When such work is completed, the planner will be able to determine storm treatment requirements necessary to prevent violation of water quality standards a given percentage of the time. Conversely, if a storm control device is planned for an area, this method of analysis will permit estimates of the reduced frequency with which standards will be contravened with the control in operation. In subsequent sections of Chapter 6, a more generalized load-reduction methodology, which considers procedures for evaluating various storm water control options, is developed.

6.3.3.1 Dissolved Oxygen

Table 6-2 indicates that the critical location for Dissolved Oxygen during the mean storm is at Milepoint 33, where a 1.63 mg/l reduction in the deficit is required. A portion of this reduction will be met by the 50 percent UOD removal at STP #1 and STP #2 necessary to meet objectives during low flow. The average storm deficit response at Milepoint 33 from STP #1 is 0.50 mg/l, and from STP #2 it is 1.00 mg/l. The 50 percent reduction, therefore, results in 0.50 (0.55 + 1.00) = 0.77 mg/l deficit reduction during the average storm. An additional reduction of 0.86 mg/l (1.63-0.77) is required to meet standards under the average storm condition. The average storm deficit response at Milepoint 33 from the combined sewer overflow is 2.00 mg/l. An effective load-reduction plan therefore requires a 43 percent (100 x 0.86/2.00) reduction in the combined sewer UOD load for the average storm event.

The storm sewer runoff load contributes 1.10 mg/l of deficit at Milepoint 33 during the average storm. If the storm-related UOD reductions are obtained equally from the combined and storm sewer loads, a 28 percent (0.86/(2.00 + 1.10)) UOD load reduction is needed at both sources.

6.3.3.2 Total Coliform Organisms

Allocation of wet-weather loads of total coliform organisms from the urban area is developed in a manner similar to that for Ultimate Oxygen Demand (UOD) allocations. Figure 5-14 indicates that the projected total coliform concentrations in the South River are dominated by storm water loadings. Two allocations are developed here to illustrate the load-reduction methodology.

The first emphasizes load reduction at the combined sewer system overflow points. In this regard, a reduction is required in the storm sewer system to reduce the peak coliform concentrations in the region between Milepoints 14 and 19 to less than the 5,000 MPN/100 ml storm-period objective. The required storm sewer reduction is:

$$\text{Percent Reduction (Storm Sewer)} = \frac{140{,}000 - 5{,}000}{140{,}000} = 96.4 \text{ percent}$$

In addition to the 96.4 percent reduction of the storm sewer load, further reductions in total coliform loads from the combined sewer system are required to meet the objective in the region below Milepoint 19. Note that background and point sources are expected to contribute 800 MPN/100 ml to the water quality condition; the combined sewers will contribute 1.15×10^6 MPN/100 ml. With the previously indicated reduction in the storm sewer load of 96.4 percent, that source will contribute about 2,500 MPN/100 ml at Milepoint 19. The reduction in total coliforms from the combined sewer system is then computed to be:

$$\text{Percent Reduction (CSO)} = \frac{(1.15 \times 10^6 + 800 + 2{,}500 - 5{,}000)}{1.15 \times 10^6}$$

$$\text{Percent Reduction (CSO)} = 99.85 \text{ percent}$$

An alternative load-reduction strategy that involves equal removals at both storm and combined sewer systems can also be developed. In this case, the computation is as follows:

CSO Impact (M.P. 19)	1.15×10^6 MPN/100 ml
Storm Sewer Impact (M.P. 19)	70,000 MPN/100 ml
Other Sources (M.P. 19)	800 MPN/100 ml
Total	1.2208×10^6 MPN/100 ml
Objective (Storm Periods)	5,000 MPN/100 ml
Percent Reduction (Storm Periods)	$\frac{(1.22 \times 10^6 - 5 \times 10^3)}{1.22 \times 10^6} = 99.65$ percent

Therefore, control of storm-related discharges sufficient to achieve 99.65 percent removal at both storm system discharges and combined sewer system overflows will also meet the required objective.

6.3.3.3 Total Suspended Solids

The water quality objective for suspended solids concentration during summer storm periods is 200 mg/l; this reflects the high background concentrations coming from non-point sources upstream of the urban area. The total background effect (Figure 5-13, pg. 5-45) is expected to be 185 mg/l at Milepoint 15. The storm sewer system which contributes the largest single component to the impact downstream of Milepoint 19 contributes an additional 280 mg/l at this point. The load reduction for suspended solids control is therefore applied to the storm sewer load as follows:

$$\text{Percent Reduction (SS)} = \frac{(185 + 280 - 200)}{280} = 94.6 \text{ percent}$$

Similarly, an objective of 250 mg/l of total suspended solids would require 77 percent removal.

$$\text{Percent Reduction (SS)} = \frac{(185 + 280 - 250)}{280} = 77 \text{ percent}$$

6.3.3.4 Nitrogen and Phosphorus

The nutrient water quality objectives in the South River study area also reflect elevated background concentrations. The objectives are set at 2.50 mg of nitrogen per liter and 6.40 mg of phosphorus per liter. Additional modeling efforts would normally be required to determine the impact of these target nutrient levels on phytoplankton productivity and weed growth in downstream areas. This would normally involve detailed numerical modeling analyses of nutrient-phytoplankton-zooplankton interactions and/or weed-

growth modeling frameworks. Both are sophisticated analytical procedures that require specialized tools and personnel thoroughly familiar with the technical issues involved in this type of modeling.

In the absence of such modeling, objectives are normally set merely to reduce nutrient levels, thereby reducing the probability of existing or potential problems. Nutrient reductions are not always required for both macronutrient species, nitrogen and phosphorus. That is, a limitation of either nutrient will normally limit the productivity of plant systems in the downstream area. Cost effectiveness of removing one nutrient preferentially over the other normally governs the load-reduction analysis in this case. Therefore, in the South River example both nutrients are allocated, but only one allocation is ultimately implemented.

The load reduction for nitrogen can be accomplished by requiring nitrogen removal at one or both plants. Figure 5-11 indicates that, if load reduction is required at only one plant, the allocation must be total (100 percent) removal at STP #2 (removal of 100 percent of the nitrogen load at STP #1 would not accomplish the objective).

Combinations of nutrient removal at both plants, however, are feasible. For example, equal percent removals at both plants is computed to be 55 percent removal of total nitrogen, a reasonable treatment level which could be achieved by some flow splitting in both plants. The allocation is computed as follows for a critical location (Milepoint 20 in Figure 5-12(a), pg. 5-44):

STP #2 Impact = 1.65 mg N/l
STP #1 Impact = 0.90 mg N/l
Total STP Impact = 2.55 mg N/l
Background Impact = 1.35 mg N/l
Objective = 2.50 mg N/l

$$\text{Percent Reduction (STP 1 and 2)} = \frac{(2.55 + 1.35 - 2.50)}{2.55} = 55 \text{ percent}$$

Similarly, the phosphorus reduction required to meet the objective (0.40 mg of phosphorus per liter) can be computed as follows:

STP #2 Impact = 0.80
STP #1 Impact = 0.50
Total STP Impact = 1.30
Background Impact = 0.10
Objective = 0.40

$$\text{Percent Reduction (STP 1 and 2)} = \frac{(1.30 + 0.10 - 0.40)}{1.30} = 77 \text{ percent}$$

The load reduction computed in this manner requires 77 percent phosphorus reduction at both treatment plants. An alternative scheme would be to remove 90-95 percent of the phosphorus at one plant, with an additional allocation to remove the remainder of the phosphorus overload from the other plant.

6.4 Methodology for the Development and Evaluation of Control Alternatives

6.4.1 Introduction

6.4.1.1 Role of the Methodology in the 208 Planning Process

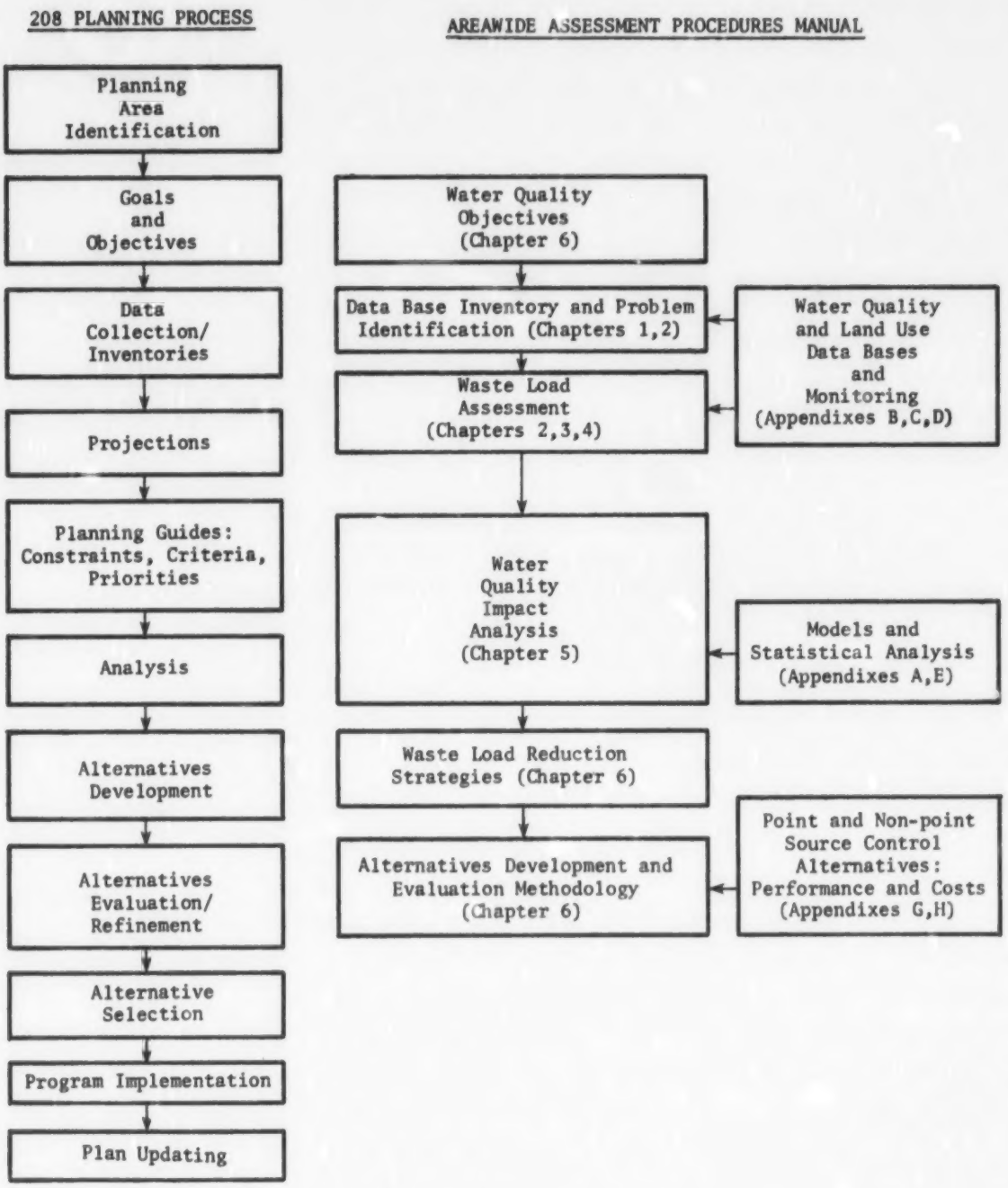
This Areawide Assessment Procedures Manual provides guidance only for certain steps of the 208 planning process. Figure 6-5 illustrates how the Chapter 6 methodology and topics addressed in other chapters in this manual fit into the overall 208 planning process. The steps of the general 208 planning process are presented as a flow chart at the left, in approximate order of their occurrence. The right side of Figure 6-5 lists the specific topics addressed in this manual, with the horizontal position of each manual topic in this flow chart corresponding to the position of the step or steps in the planning process which the topic represents. The general planning steps which have no corresponding topics in the manual are covered by other EPA guidance documents.

Figure 6-5 also shows the relationships among different parts of this manual. Chapters 1 through 4 cover problem identification and load assessment, Chapter 5 addresses analysis of the water quality impact of the wastewater loads, and Chapter 6 presents guidance for three key areas: water quality objectives, load-reduction strategies, and control alternatives. The selection of water quality objectives forms the basis for determining the type and degree of wastewater source control. Various load-reduction strategies for meeting the objectives are formulated, as explained earlier in this chapter. These strategies deal with the number and types of sources to be controlled and the amount of load reduction to be achieved at each source. Finally, control alternatives are developed on the basis of performance capabilities, and are evaluated for their monetary costs. The result is an identification of the cost of control alternatives which can achieve the desired water quality objectives.

The appendixes to the manual support various chapters, as shown in Figure 6-5. For example, Appendixes G and H contain performance and cost data for the development and evaluation of control alternatives, which are covered in Chapter 6. Specifically, Appendix G contains information on urban non-point source control alternatives, including land management and collection system

FIGURE 6-5

RELATIONSHIP OF CHAPTER 6 METHODOLOGY
TO 208 PLANNING PROCESS


208 PLANNING PROCESS
AREAWIDE ASSESSMENT PROCEDURES MANUAL
Planning Area Identification
Goals and Objectives
Data Collection/ Inventories
Projections
Planning Guides: Constraints, Criteria, Priorities
Analysis
Alternatives Development
Alternatives Evaluation/ Refinement
Alternative Selection
Program Implementation
Plan Updating
Water Quality Objectives (Chapter 6)
Data Base Inventory and Problem Identification (Chapters 1,2)
Waste Load Assessment (Chapters 2,3,4)
Water Quality Impact Analysis (Chapter 5)
Waste Load Reduction Strategies (Chapter 6)
Alternatives Development and Evaluation Methodology (Chapter 6)
Water Quality and Land Use Data Bases and Monitoring (Appendixes B,C,D)
Models and Statistical Analysis (Appendixes A,E)
Point and Non-point Source Control Alternatives: Performance and Costs (Appendixes G,H)

controls. Appendix H contains performance data and cost curves for continuous and intermittent point source control alternatives, including wastewater and residuals treatment systems, and wet-weather storage and treatment units.

The appendixes may be used as sources of performance and cost data to support calculations and alternatives evaluation based on methodologies outlined in this chapter. Before applying the methodologies, the user should study carefully the introductions to the appendixes to understand the assumptions and design basis upon which the cost curves were developed. Only certain costs have been specifically included in the cost curves. In order to develop total cost estimates, the user must add allowances for the factors, such as engineering design and contingencies.

Of course, sources of cost information other than Appendixes G and H may be utilized for any of the necessary determinations. Here again, the user must be careful to investigate which factors have been included in the estimate being used so that it will be consistent with other cost information.

In the Chapter 6 methodology, the performance data are used to determine the technological feasibility of a particular control alternative and the size or number of control devices necessary to achieve the required load reduction. The cost curves or equivalent sources are then utilized to determine the associated monetary cost.

6.4.1.2 Monetary Cost

The Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500) specify cost-effectiveness as the principal criterion for the planning and development of wastewater management programs as those programs relate to municipal treatment works and to the control of combined sewer overflows and storm sewer discharges. EPA has defined cost-effectiveness analysis as a systematic comparison of alternatives to identify the solution which minimizes total costs to society over a defined planning period to meet given goals and objectives in a reliable manner. Section 208(b)(2)(e) specifies that the plan, in determining the total cost to society, should document the economic, social, and environmental costs as well as the capital, operating, administrative, and maintenance costs of implementing the control alternatives. These latter costs can usually be quantified in monetary terms, but the

economic, social, and environmental costs are more difficult to quantify and may require description and evaluation using more subjective techniques.

Monetary costs tend to receive most of the planner's attention in cost-effectiveness analysis. Also, decision-makers tend to be oriented toward cash outlays and toward the financial aspects of 208 planning implementation; in fact, many public advisors and government officials are not at all accustomed to dealing with and making decisions based on non-monetary cost factors. Nevertheless, the 208 engineer or planner has the responsibility to identify and present all significant costs (both monetary and non-monetary) when considering control alternatives.

Other 208 guidance documents provide guidelines for social, economic, and environmental impacts and cost analysis. This manual deals only with the determination of the monetary cost associated with implementing the various techniques presented. However, this should not be construed to mean that the user should orient his cost-effectiveness analysis so closely to monetary costs that the other cost considerations are overlooked or obscured. Also, alternatives should not be eliminated from further evaluation solely because of a high monetary cost relative to other alternatives. The consideration of non-monetary or non-quantifiable factors may result in a low monetary-cost alternative actually having a high total cost to society. Conversely, further analysis may render an alternative with high monetary cost very attractive because of public sensitivities or other localized factors. For these reasons, the Chapter 6 methodology is not intended to serve as the only guide to the user for selecting or eliminating a control alternative from further consideration.

In some cases, pre-screening of specific applications of a control alternative will be made on the basis of least monetary cost. For example, the most promising (least-cost) sites among a number of potential sites will be chosen in the initial evaluation of land application as a feasible control alternative. If the land application approach is still attractive after other factors have been evaluated, a more detailed analysis procedure may be employed to assure that the most cost-effective land application sites have been identified. As far as this methodology is concerned, all control

alternatives which are found to be feasible from a performance point of view will be evaluated for monetary cost, unless the user chooses not to do so for other reasons.

6.4.1.3 Relative Reliability of Performance and Cost information

Monetary-cost comparisons should not be the sole basis for selecting control alternatives, but at some point in the selection process the relative costs of various alternatives must be considered. Therefore, it is very important for the engineer or planner to understand the reliability of the information upon which the cost figures are based.

The reliability of performance data must also be considered, because this type of information frequently is the basis for determining the size of treatment units or other control devices needed for a particular control alternative. This section covers the use of the performance and cost information of Appendixes G and H, and provides a method for assuring adequate consideration of the relative reliability of the various inputs of information (performance and cost) involved in comparison of the cost of various control alternatives.

The performance data and cost information in Appendixes G and H are utilized to determine the monetary cost of feasible control alternatives for addressing water quality problems in 208 planning areas. Performance data for a particular control alternative are compared to a required standard to assess the alternative's capability to meet the standard. Then the monetary costs of those alternatives which meet the performance requirements are determined by utilizing the cost curves. Since performance and cost information for one alternative may be based on much more extensive data and experience than the information for another alternative, the reliability of both the cost information and the performance information should be taken into account when considering relative cost and performance capabilities.

The reliability of information is especially important in developing, evaluating, and selecting control alternatives for areawide water quality management, because there are highly varying degrees of experience with the various control alternatives. For example, an abundance of cost figures and

estimates are available to substantiate performance and cost curves for an activated sludge treatment plant. Less data and experience are available to substantiate performance and cost relationships for street sweeping as an alternative in control of pollution from urban runoff. Even less data and experience are available to substantiate performance and cost estimates for various land management alternatives such as zoning. Although each of these three alternatives is known to be effective in reducing pollutant levels, determination of the best combination will require careful deliberation, good judgment, and full recognition of the reliability of each type of information at the time the decision is made.

The concept of "relative reliability" is presented here to aid the user of this manual in comparing the monetary cost of control alternatives. Five levels of relative reliability are used to identify the nature and extent of the experience and data upon which the cost and performance information is based:

- Level A indicates estimates based on detailed breakdowns of all pertinent cost elements and is supported by detailed engineering data. This level of reliability is always based on site-specific information. The relative reliability of information in this level is ± 15%. For example, facilities-planning estimates (Section 201 of P.L. 92-500) represent Level A information reliability.

- Level B indicates that the data and experience on a particular control alternative are sufficient only to establish a relationship, as expressed by a table of data or a single curve or family of curves. The relative reliability of information at this level is ± 30%. For example, general cost curves such as the wastewater treatment systems curves and process curves presented in Appendix H represent Level B information reliability.

- Level C indicates that the data and experience are sufficient only to establish a range of values for cost or performance. The relative reliability of information at this level is ± 50%. For example, street sweeping estimates, such as those in Appendix G, represent Level C information reliability.

- Level D indicates that the data and experience are sufficient only to establish the relative order of magnitude of the cost and performance characteristics.
- Level E indicates that the data or experience is insufficient to establish any level of cost or performance estimate, or that site-specific factors are so critical to the performance and cost that a general estimate should not be made.

This manual does not present guidelines on the application of the relative reliability concept for particular situations. Rather, the application by the user will be a function of the control alternatives that are being compared, the closeness of the cost or performance estimates, the background of the user, the consequences of error, and other factors.

The "relative reliability" concept is introduced to emphasize to the user that comparisons of cost or performance estimates prepared using this manual are only as reliable as the lowest level of reliability assigned to the control alternatives being considered. The concept is particularly well suited to compare more traditional engineering approaches to load reduction with "emerging" non-structural control techniques whose costs and relative effectiveness have not been satisfactorly evaluated or sufficiently documented.

6.4.1.4 Organization

The methodology consists of: 1) a framework methodology for directing the user through the methodology operations; and 2) a number of component methodologies for investigating specific control alternatives. The framework methodology guides the user through the entire process of developing and evaluating control alternatives, including the determination of one or more feasible alternatives for controlling each source under each load-reduction strategy. The component methodologies are designed to facilitate the determination of the feasibility and monetary cost of implementing a particular control alternative for a wastewater source of concern.

Both the framework and the components are presented in Section 6.4.2. An example illustrating the use of the methodology in a hypothetical planning area

is presented in Section 6.5 as a further aid to the user.

6.4.1.5 Methodology Characteristics

In order that the user may better understand and use this methodology, certain characteristics of the methodology are discussed in the following paragraphs.

The methodology is a logical approach to addressing various pollution problems. It shows the relationship between various types of pollution problems and feasible control alternatives, and illustrates a logical sequence for addressing the problems.

The methodology involves a level of detail which is consistent with the 208 level of analysis. Assumptions and simplifications are made throughout the methodology to facilitate the development of cost estimates with a minimum of site-specific data gathering or use of sophisticated analytical techniques and calculations.

The calculations, engineering assumptions, and judgments used in the methodology allow the user to arrive at a particular determination or answer. The methods presented herein should not be interpreted as the only possible approach. New data, additional information, or advanced techniques may be substituted at any point for those suggested in the methodology. The function of the methodology is to illustrate the interfacing and logical timing of determinations, rather than to present a rigid or all inclusive list of control alternatives. The user should not hesitate to use other data or techniques if he has the necessary information and expertise.

The methodology has been designed for ease of understanding and application. Both the framework methodology and the component methodologies include: 1) logic summary, 2) a detailed operations flowchart, 3) worksheets, and 4) notes on specific operations in order to facilitate understanding and use. Also, the methodology is designed so that the major determinations can be accomplished by hand calculations, with a minimal requirement for outside data or special expertise.

The methodology is comprehensive in that it deals with point (continuous and intermittent) and non-point sources of pollution, and with structural and non-structural alternatives for controlling these sources. However, it does

not provide all the detailed analytical techniques or background information needed to analyze all aspects of the implementation of a specific control alternative, such as information on funding, siting, or staging of facilities, and other detailed engineering determinations. These considerations can be explored separately if they are found to be critical to the development and evaluation of alternatives. However, the methodology does suggest where the considerations should be injected into the analysis and how they relate to other parts.

The methodology provides for several levels of analysis. Depending on the complexity of the planning area (i.e., the numbers and types of sources, the degree and complexity of water quality problems, the size of the area, population, etc.), the methodology can be used to identify the most effective general approaches to the problems, or can be used to perform a more detailed evaluation of individual sources for a specific water quality problem. For example, if a number of point sources are in close proximity, their wastewater loads may be aggregated to simplify both the water quality impact analysis and the investigation of control alternatives. The methodology may be used to investigate the necessity for an improvement in the level of treatment of the aggregated load or the elimination of that load by application to the land, or other appropriate alternatives. In addition, the methodology can be used to refine this analysis by segregating loads and investigating the treatment process alternatives at a particular site, when this is of interest. Thus, the methodology is flexible in that the level of analysis can be adjusted to the level of complexity of the area and to the particular problems or control alternatives of interest.

6.4.2 Methodology

6.4.2.1 Use of the Methodology

Content

The presentation of the framework and component methodologies includes:

1. Introduction - relates in general terms the objectives of the procedure or the control alternative.

2. Logic Summary - summarizes the basic logic on which the procedure is based, by listing the major steps involved.

3. Flowchart - presents the detailed steps involved in carrying out the procedure. (These steps are expansions of steps listed in the foregoing logic summary and include references to the Worksheets.)

4. Worksheet - suggests one of several methods for recording the determinations, calculations, comparisons, and assumptions called for in the flowchart. There is a cross-reference between each flowchart step requiring an operation and the corresponding item in the worksheet. The Logic Summary and Flowchart can be used with other types of worksheets or guidelines for calculations. The Worksheets included herein are a suggested approach to aid the user in performing the evaluations.

5. Notes - cover assumptions, reference information and sources, and explanations related to specific flowchart or worksheet items.

The worksheets for each procedure are designed to be copied for repeated use. They can be filled out and stored as the user proceeds through the framework and the component methodologies to document the decisions, calculations, and cost determinations. The FRAMEWORK METHODOLOGY WORKSHEET, Table 6-3, is used to summarize the monetary cost and reliability information for all control alternatives considered for each source, and for monitoring progress in considering load-reduction strategies and sources. Worksheets for the components should be placed behind the framework worksheet, Table 6-3, in the order in which they are considered. The illustrative example in Section 6.5 includes a sample set of worksheets used in the development and evaluation of control alternatives for the hypothetical South River planning area.

The Logic Summary, Flowchart, and Worksheets offer increasing levels of sophistication and detail in the evaluation of control alternatives. The user should use the level of detail which best fits his particular situation and needs. In addition, other techniques or approaches to specific operations within any of the component methodologies should be substituted where the user desires or has more up-to-date or site-specific information.

Level of Analysis

Difficulties may arise when determining the appropriate level of analysis. These difficulties arise from the complexity of many planning areas, the dissimilarity of the alternatives being compared, the various degrees of detail necessary to adequately characterize various alternatives, and the variability in the quantity and quality of information available on various alternatives.

The level of analysis for a particular planning area will be a function of the complexity of the area, the types of pollution sources, and the amount of information readily available on these sources. Highly complex areas will require the use of simplifying assumptions (e.g., aggregation of loads); this tends to decrease the usefulness of the performance and cost determinations if specific sites or sources are of concern.

However, the objective of the overall process must be kept in mind, i.e., to obtain a preliminary evaluation of various approaches to areawide problems. Also, depending on the particular needs and/or background of the planner or engineer using the manual, the methodology determinations may be based on site-specific information, actual data in place of assumptions, or more sophisticated techniques if these are available. In addition, if the area is complex and if loads have been aggregated and assumptions made, the methodology may be applied a second time in order to examine in more detail the sources or alternatives of particular interest.

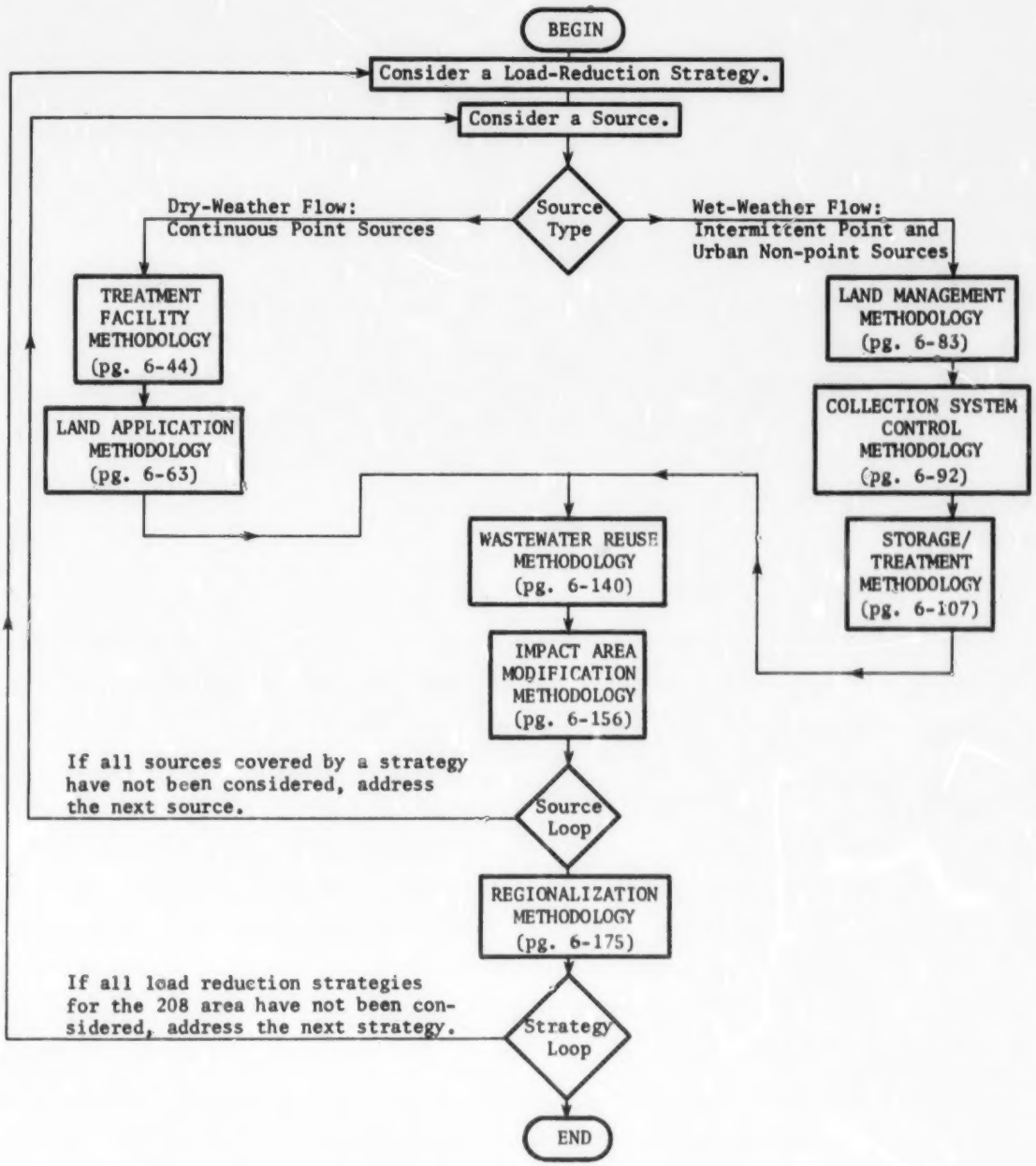
6.4.2.2 Framework Methodology

Discussion

The FRAMEWORK METHODOLOGY is a guide for the entire process of developing and evaluating control alternatives. Within this framework, the user considers each source under each load-reduction strategy, and investigates various control alternatives for that source. The investigation of control alternatives is accomplished by using component methodologies applicable to the wastewater sources involved. An overview of the FRAMEWORK METHODOLOGY is presented in Figure 6-6, which shows the position of the component methodologies in the framework.

FIGURE 6-6

FRAMEWORK METHODOLOGY
OVERVIEW


BEGIN
Consider a Load-Reduction Strategy.
Consider a Source.
Source Type
Dry-Weather Flow: Continuous Point Sources
Wet-Weather Flow: Intermittent Point and Urban Non-point Sources
TREATMENT FACILITY METHODOLOGY (pg. 6-44)
LAND APPLICATION METHODOLOGY (pg. 6-63)
LAND MANAGEMENT METHODOLOGY (pg. 6-83)
COLLECTION SYSTEM CONTROL METHODOLOGY (pg. 6-92)
STORAGE/ TREATMENT METHODOLOGY (pg. 6-107)
WASTEWATER REUSE METHODOLOGY (pg. 6-140)
IMPACT AREA MODIFICATION METHODOLOGY (pg. 6-156)
If all sources covered by a strategy have not been considered, address the next source.
Source Loop
REGIONALIZATION METHODOLOGY (pg. 6-175)
If all load reduction strategies for the 208 area have not been considered, address the next strategy.
Strategy Loop
END

The FRAMEWORK METHODOLOGY logic considers two basic types of sources: wet-weather sources and dry-weather sources. As shown in Figure 6-6, wet-weather sources of interest fall into two general categories: 1) intermittent point sources (such as separate storm and combined sewer overflows); and 2) non-point sources (such as runoff from construction sites, landfill sites, and urbanized areas). Dry-weather sources of greatest concern are continuous point source discharges, such as municipal and industrial wastewater effluents. Figure 6-6 shows the component methodologies for investigating control alternatives for the two types of wastewater flows.

Wet-weather wastewater flows can be handled at several points. The LAND MANAGEMENT METHODOLOGY covers control alternatives which can be used to reduce the quantity of runoff or the runoff loadings at the source. The COLLECTION SYSTEM CONTROL METHODOLOGY covers alternatives which can be applied to flows after they enter the collection system to reduce the quantity of flow or pollutant load that reaches the stream as an overflow or bypass. Finally, the STORAGE/TREATMENT METHODOLOGY covers alternatives to store and treat overflows at the end of the collection system to reduce the pollutant loadings.

Dry-weather wastewater flows from continuous point sources are generally managed by treatment and discharge to a receiving water, or by treatment and application to the land. The TREATMENT FACILITY METHODOLOGY covers new-plant construction or plant expansion and upgrading, and the LAND APPLICATION METHODOLOGY covers application of wastewater to the land after some level of pretreatment at a facility.

Control alternatives common to both wet- and dry-weather flows are considered in WASTEWATER REUSE METHODOLOGY, IMPACT AREA MODIFICATION METHODOLOGY, and REGIONALIZATION METHODOLOGY. Several component methodologies which are utilized by other of the component methodologies are not shown in Figure 6-6 because they are not employed separately. These are the TRANSPORTATION METHODOLOGY, RESIDUALS DISPOSAL METHODOLOGY, and PRESENT-WORTH METHODOLOGY.

A component methodology guides the user in determining if the performance capability of a control alternative for a particular source meets the requirements of the load-reduction strategy. Then, the monetary cost of

implementing the control alternative is determined.

Methodology Logic

A summary of the logic of the FRAMEWORK METHODOLOGY is presented in Figure 6-7. An expanded flowchart, Figure 6-8, lists the steps to be taken in determining performance and costs. The worksheets for recording the operations are presented as Table 6-3. Notes on specific steps or worksheet items are presented after the worksheets.

FIGURE 6-7

FRAMEWORK METHODOLOGY
LOGIC SUMMARY

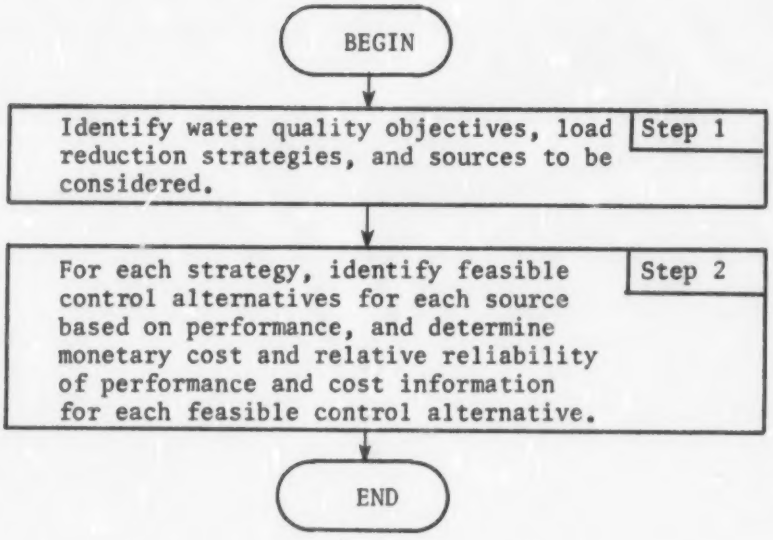

BEGIN
Identify water quality objectives, load reduction strategies, and sources to be considered.
Step 1
For each strategy, identify feasible control alternatives for each source based on performance, and determine monetary cost and relative reliability of performance and cost information for each feasible control alternative.
Step 2
END

FIGURE 6-8

FRAMEWORK METHODOLOGY
FLOWCHART

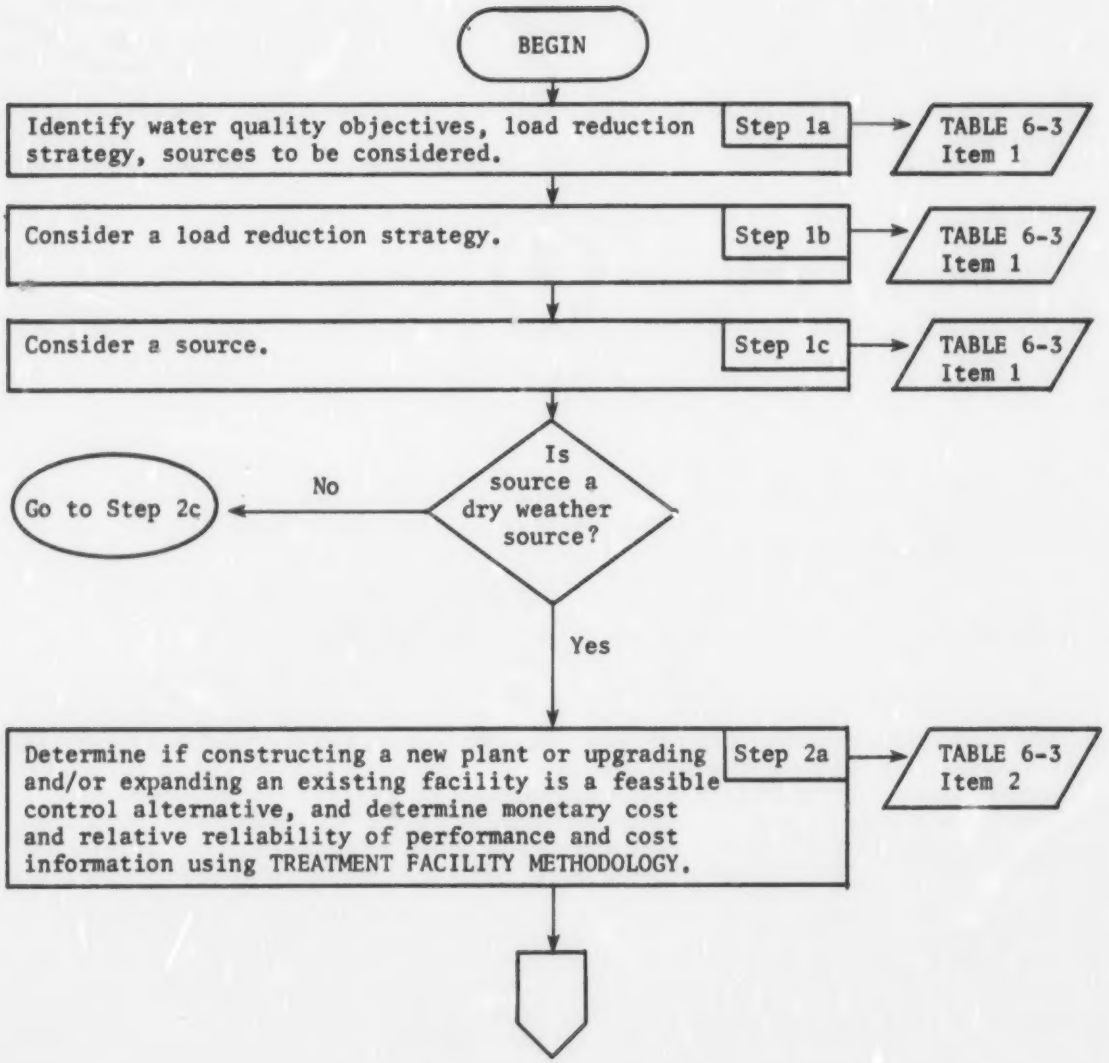

BEGIN
Identify water quality objectives, load reduction strategy, sources to be considered.
Step 1a
TABLE 6-3 Item 1
Consider a load reduction strategy.
Step 1b
TABLE 6-3 Item 1
Consider a source.
Step 1c
TABLE 6-3 Item 1
Is source a dry weather source?
No
Go to Step 2c
Yes
Determine if constructing a new plant or upgrading and/or expanding an existing facility is a feasible control alternative, and determine monetary cost and relative reliability of performance and cost information using TREATMENT FACILITY METHODOLOGY.
Step 2a
TABLE 6-3 Item 2

FIGURE 6-8 (CONTINUED)

FRAMEWORK METHODOLOGY
FLOWCHART

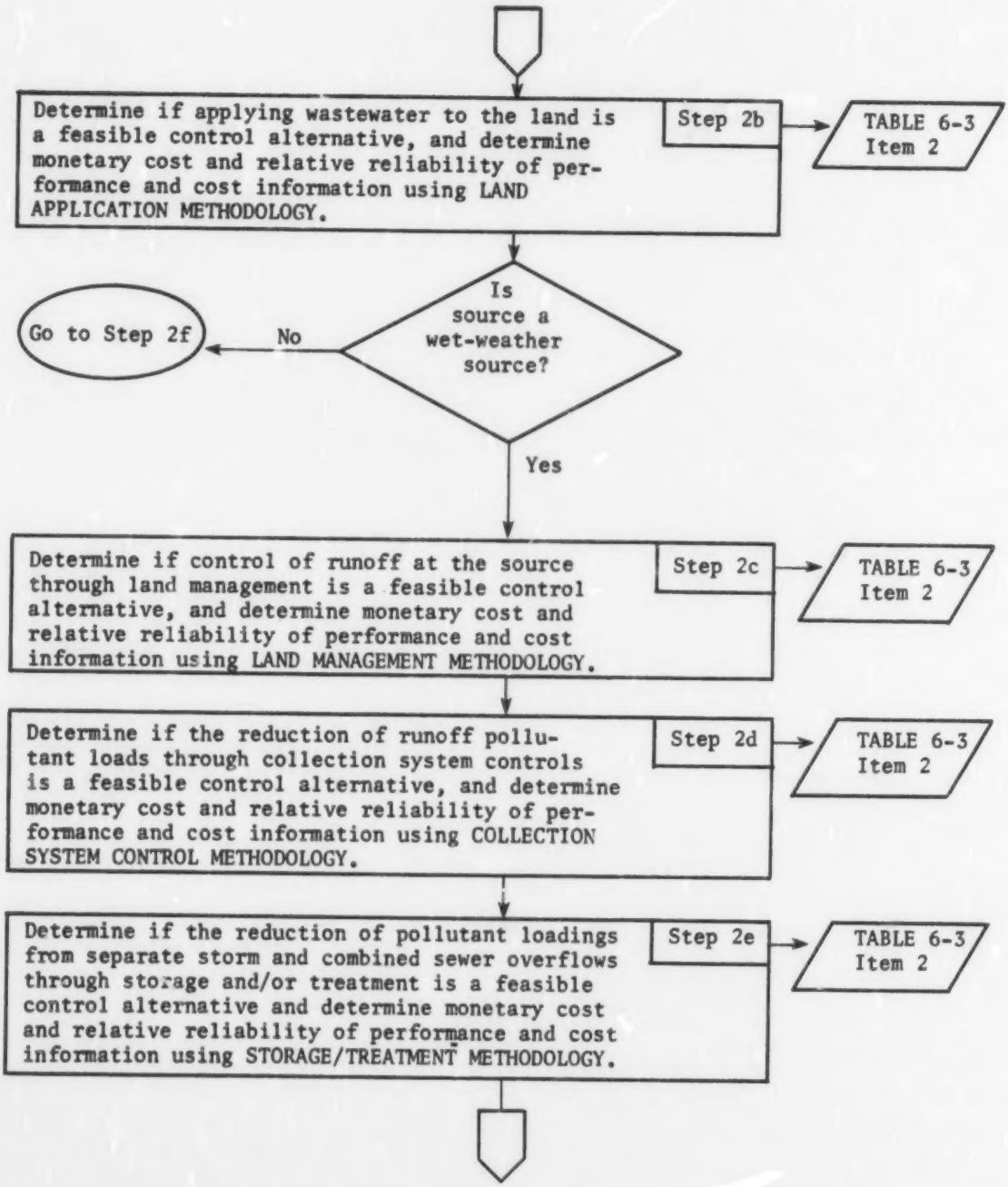

Determine if applying wastewater to the land is a feasible control alternative, and determine monetary cost and relative reliability of performance and cost information using LAND APPLICATION METHODOLOGY.
Step 2b
TABLE 6-3 Item 2
Is source a wet-weather source?
No
Go to Step 2f
Yes
Determine if control of runoff at the source through land management is a feasible control alternative, and determine monetary cost and relative reliability of performance and cost information using LAND MANAGEMENT METHODOLOGY.
Step 2c
TABLE 6-3 Item 2
Determine if the reduction of runoff pollutant loads through collection system controls is a feasible control alternative, and determine monetary cost and relative reliability of performance and cost information using COLLECTION SYSTEM CONTROL METHODOLOGY.
Step 2d
TABLE 6-3 Item 2
Determine if the reduction of pollutant loadings from separate storm and combined sewer overflows through storage and/or treatment is a feasible control alternative and determine monetary cost and relative reliability of performance and cost information using STORAGE/TREATMENT METHODOLOGY.
Step 2e
TABLE 6-3 Item 2

FIGURE 6-8 (CONTINUED)

FRAMEWORK METHODOLOGY
FLOWCHART

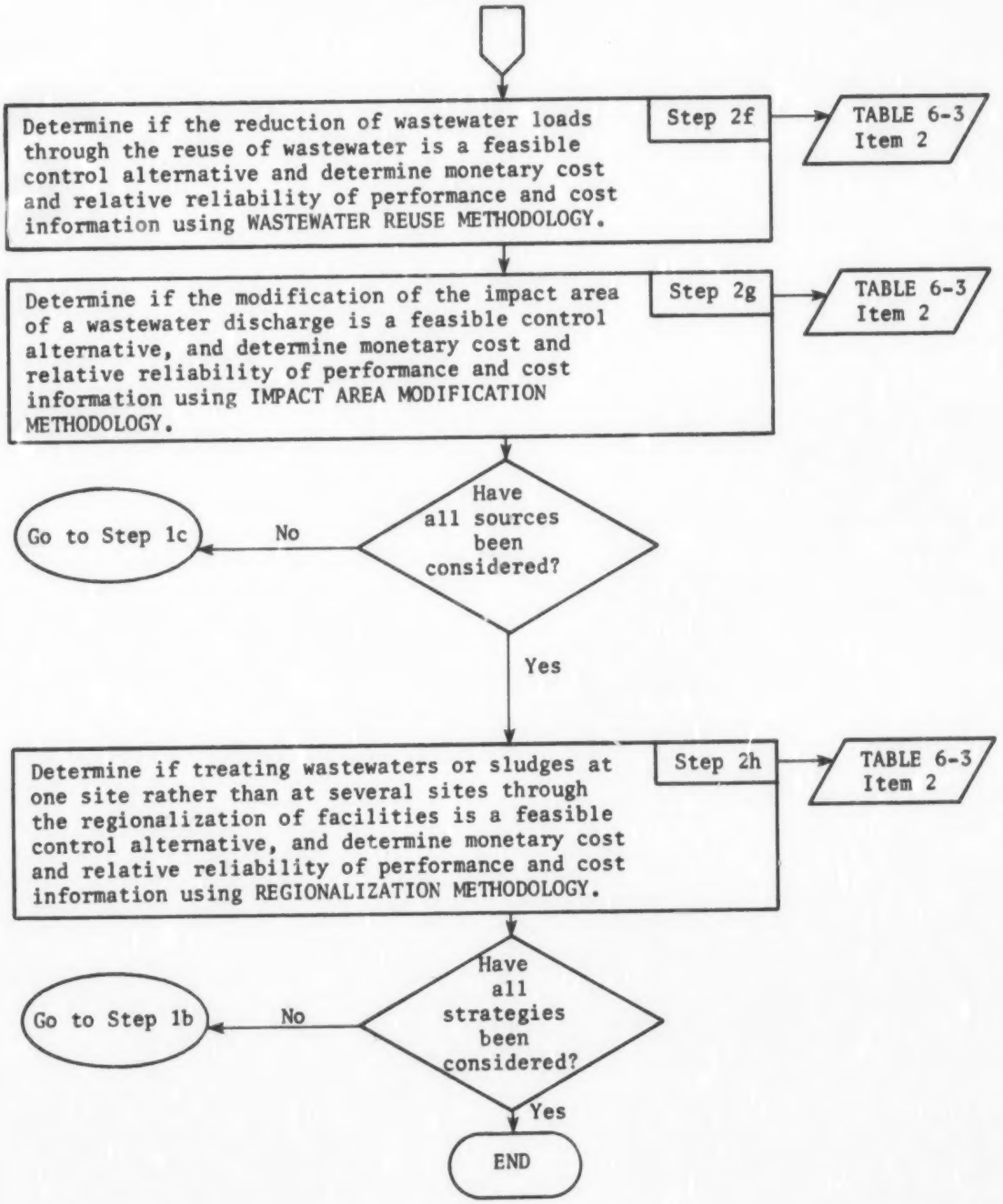

Determine if the reduction of wastewater loads through the reuse of wastewater is a feasible control alternative and determine monetary cost and relative reliability of performance and cost information using WASTEWATER REUSE METHODOLOGY.
Step 2f
TABLE 6-3 Item 2
Determine if the modification of the impact area of a wastewater discharge is a feasible control alternative, and determine monetary cost and relative reliability of performance and cost information using IMPACT AREA MODIFICATION METHODOLOGY.
Step 2g
TABLE 6-3 Item 2
Have all sources been considered?
No
Go to Step 1c
Yes
Determine if treating wastewaters or sludges at one site rather than at several sites through the regionalization of facilities is a feasible control alternative, and determine monetary cost and relative reliability of performance and cost information using REGIONALIZATION METHODOLOGY.
Step 2h
TABLE 6-3 Item 2
Have all strategies been considered?
No
Go to Step 1b
Yes
END

TABLE 6-3
FRAMEWORK METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgments presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach available (or even as the preferred approach). However, any approaches used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other EPA, State, and local guidelines and regulations.

Item 1

i. Identification of water quality objectives, load reduction strategies, and sources.

a. Define water quality objectives by number and parameters to be controlled.

	Receiving Water Constituents to be Controlled					
Water Quality Objective #	D.O. (Dry Weather)	D.O. (Wet Weather)	Total Suspended Solids (Wet Weather)	Total Nitrogen	Total Phosphorus	Total Coliforms (Wet Weather)

b. Load reduction strategies represent differing percentage reductions in load at the various sources of interest for a particular water quality objective. These strategies are identified by a letter (a, b, c, etc.) where more than one strategy is proposed for a particular water quality objective.

c. Identify sources by number:

Source #	Source Type (Wet or Dry)	Source Description

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

TABLE 6-3 (continued)
FRAMEWORK METHODOLOGY
WORKSHEET

Item 1 (continued)

ii. Record of load reduction strategies and sources considered.

- Check (x) the sources to be considered under each load-reduction strategy.
- Circle the checks in the matrix after all appropriate control alternatives have been considered for a source.
- Go to next load reduction strategy when all sources have been considered for that strategy.
- End when all strategies have been considered.

Load Reduction Strategy	Source Number					
	1	2	3	4	5	6

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

TABLE 6-3 (continued)
FRAMEWORK METHODOLOGY
WORKSHEET

Item 2 - Feasible Control Alternatives.

i. Record the Present-Worth cost of control alternatives determined using the component methodologies.

ii. Record the worksheet page number (from lower right corner) where the present worth is recorded in the appropriate component methodology.

iii. Record the relative reliability of the performance and cost information for the control alternative as identified in Appendixes G and H or at the discretion of the user.

Load Reduction Strategy	Source	Control Alternative	Present-Worth $	Page	Information Reliability Performance	Cost

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

Notes on Methodology Logic

Step 1 (Item 1i) - The determination of water quality objectives and the development of load-reduction strategies to achieve these objectives should take place before the development and evaluation of control alternatives.

The water quality constituents to be controlled in order to achieve each objective are identified in Item 1i. As explained in the worksheet, a load-reduction strategy states the degree to which various sources are to be controlled in order to reduce pollutant loadings. There may be several strategies for achieving each water quality objective. For this manual, any reference to a load-reduction strategy should be taken as a reference to the strategy water quality objective combination. Also, the sources of interest in the study area are numbered for ease of reference.

Step 1 (Item 1ii) - The framework methodology is employed as an iterative technique to investigate feasible control alternatives for each source within each load-reduction strategy. Step 1 guides the user through the selection of the particular load-reduction strategy and source that he will be looking at for any particular iteration. Later steps in the framework methodology bring the user back to these steps if there is another source to be considered for one particular load-reduction strategy, or for other load-reduction strategies to be considered for the planning area.

Also, Item 1ii of the control methodology worksheet provides a place for the user to keep track of exactly where he is in the iterations.

The control box just after Step 1c directs the user to the appropriate steps in the flowchart, depending on whether he is considering a wet-weather source or a dry-weather source.

Step 2 (Item 2) - This step sends the user to the appropriate component methodology in order to test the feasibility of the control alternative and to determine the monetary cost. The cost and information reliability (from Appendixes G and H) for each control alternative considered is recorded in Item 2.

6.4.2.3 Treatment Facility Methodology

Discussion

The purpose of this methodology is to identify the monetary costs incurred in treating a wastewater to meet a specific effluent quality. This methodology will identify the cost for constructing new facilities, expanding existing facilities, upgrading existing facilities, or expanding and upgrading existing facilities.

The TREATMENT FACILITY METHODOLOGY provides the user with an approach that will develop the facility costs in the desired detail. It should be noted, however, that in the 208 planning process, generalized treatment levels such as those present in the treatment system curves in Appendix H (e.g., secondary treatment, advanced waste treatment, etc.) will usually be sufficient to provide ample cost information for making decisions in the overall management picture. However, in many cases, the user may have site-specific facility data (e.g., 201 facilities plans) which will provide cost estimates of a higher confidence level.

The TREATMENT FACILITY METHODOLOGY facilitates consideration of phased construction for a control alternative capable of meeting the effluent criteria based on population growth characteristics within the planning area. Therefore, the facility cost that is being developed will be based on a more realistic consideration of the time-value of project costs. The methodology also encourages and facilitates the evaluation of existing facility utilization. It should be noted, however, that upgrading and expanding existing facilities which are old, outmoded, etc., often represents a financial drawback. For example, upgrading or expanding an existing facility, and working in and around existing equipment, often requires non-optimal construction techniques. A correlation is presented in Appendix H, Figure H-1, that shows a relation between the additional cost associated with expansion as a function of the expansion flow. This can serve as a rough guide for estimating the increased capital associated with expansions.

Also, provisions are included to identify the costs for replacing worn-out equipment at the end of its service life, and also for crediting value to salvageable equipment at the end of the planning period. This should ensure

that proper consideration has been given to all major factors that influence economical comparisons of facilities.

While not specifically addressed in the TREATMENT FACILITY METHODOLOGY, the user should consider other factors such as siting requirements and site characteristics (e.g., flood hazards, surrounding land uses, utilities, and rail and highway access) in evaluating treatment alternatives. These factors will reflect not only differential costs, but also comparative site suitability. Consideration of these factors should be coordinated with the REGIONALIZATION METHODOLOGY. For additional guidance in facilities planning, the user should consult references (12) and (13).

Methodology Logic

A summary of the logic of the TREATMENT FACILITY METHODOLOGY is presented in Figure 6-9. An expanded flowchart, Figure 6-10, lists the steps to be taken in determining performance and costs. The worksheets for recording the operations are presented as Table 6-4. Notes concerning the methodology steps and worksheet items are presented after the worksheets.

FIGURE 6-9

TREATMENT FACILITY METHODOLOGY
LOGIC SUMMARY

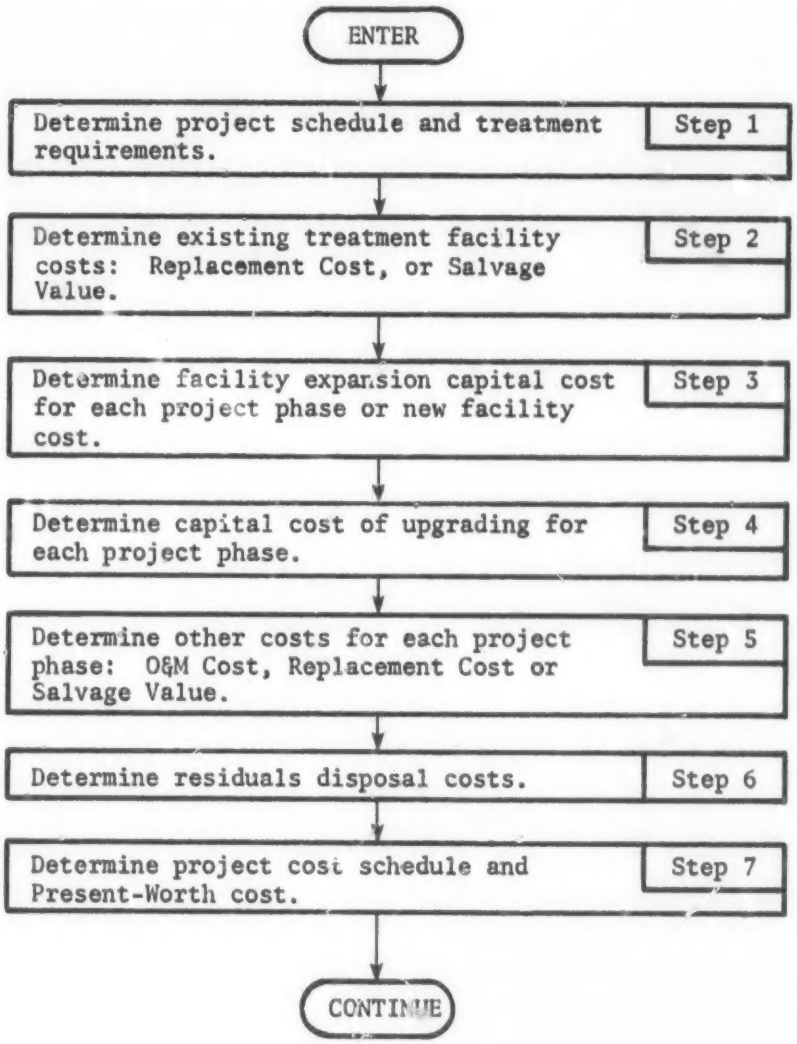

ENTER
Determine project schedule and treatment requirements.
Step 1
Determine existing treatment facility costs: Replacement Cost, or Salvage Value.
Step 2
Determine facility expansion capital cost for each project phase or new facility cost.
Step 3
Determine capital cost of upgrading for each project phase.
Step 4
Determine other costs for each project phase: O&M Cost, Replacement Cost or Salvage Value.
Step 5
Determine residuals disposal costs.
Step 6
Determine project cost schedule and Present-Worth cost.
Step 7
CONTINUE

FIGURE 6-10

TREATMENT FACILITY METHODOLOGY
FLOWCHART

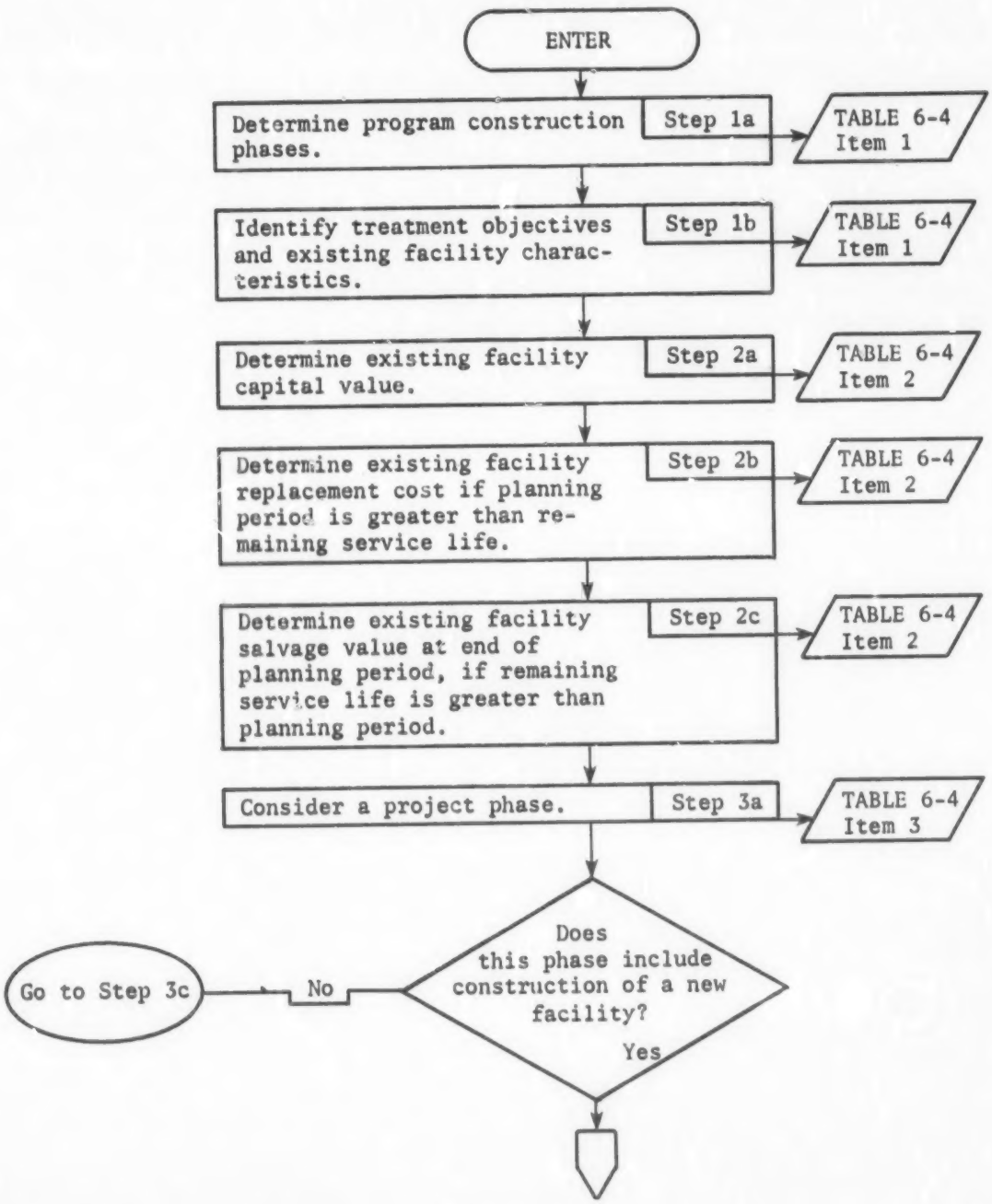

ENTER
Determine program construction phases.
Step 1a
TABLE 6-4 Item 1
Identify treatment objectives and existing facility characteristics.
Step 1b
TABLE 6-4 Item 1
Determine existing facility capital value.
Step 2a
TABLE 6-4 Item 2
Determine existing facility replacement cost if planning period is greater than remaining service life.
Step 2b
TABLE 6-4 Item 2
Determine existing facility salvage value at end of planning period, if remaining service life is greater than planning period.
Step 2c
TABLE 6-4 Item 2
Consider a project phase.
Step 3a
TABLE 6-4 Item 3
Does this phase include construction of a new facility?
No
Go to Step 3c
Yes

FIGURE 6-10 (CONTINUED)

TREATMENT FACILITY METHODOLOGY
FLOWCHART

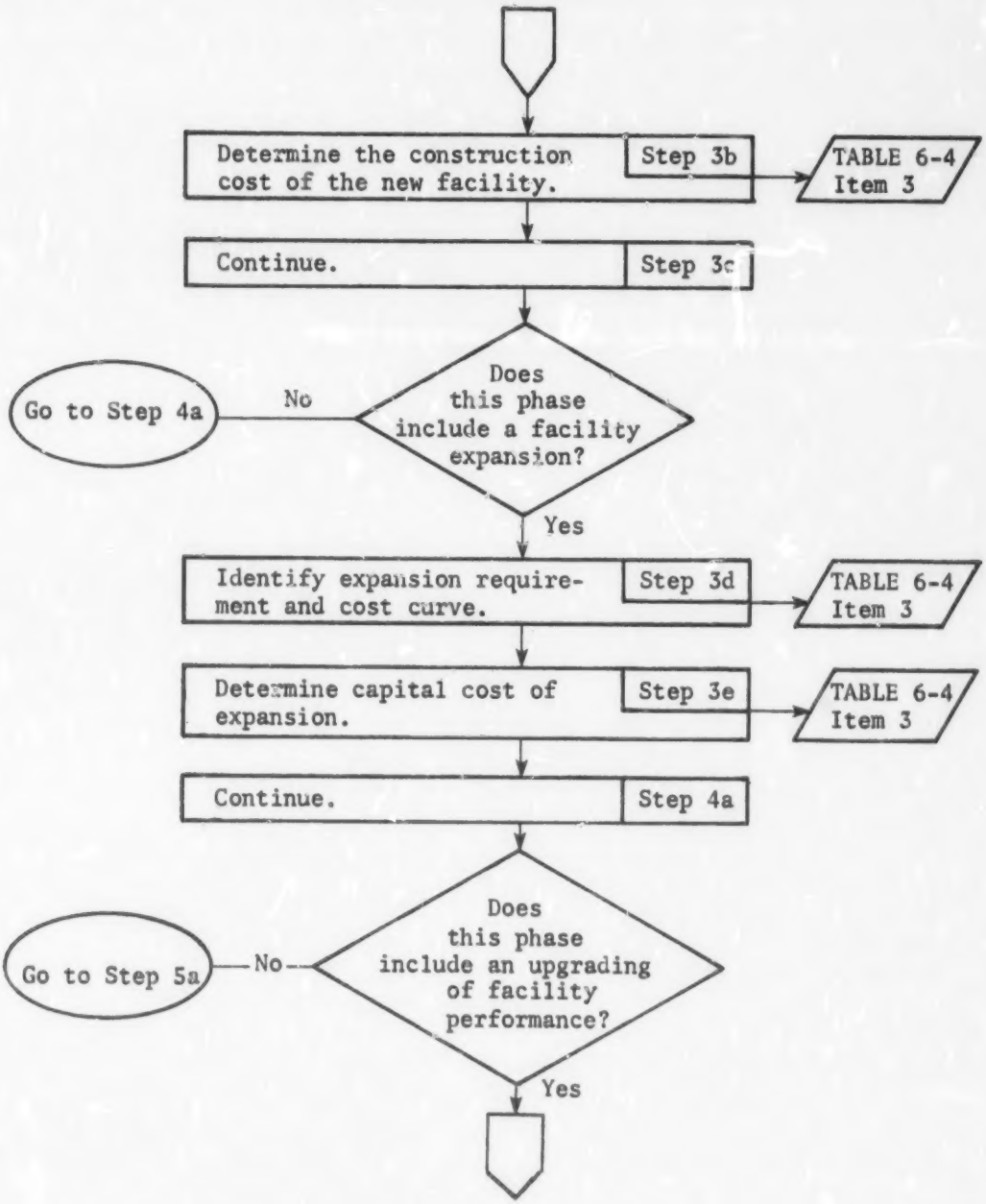


FIGURE 6-10 (CONTINUED)

TREATMENT FACILITY METHODOLOGY
FLOWCHART

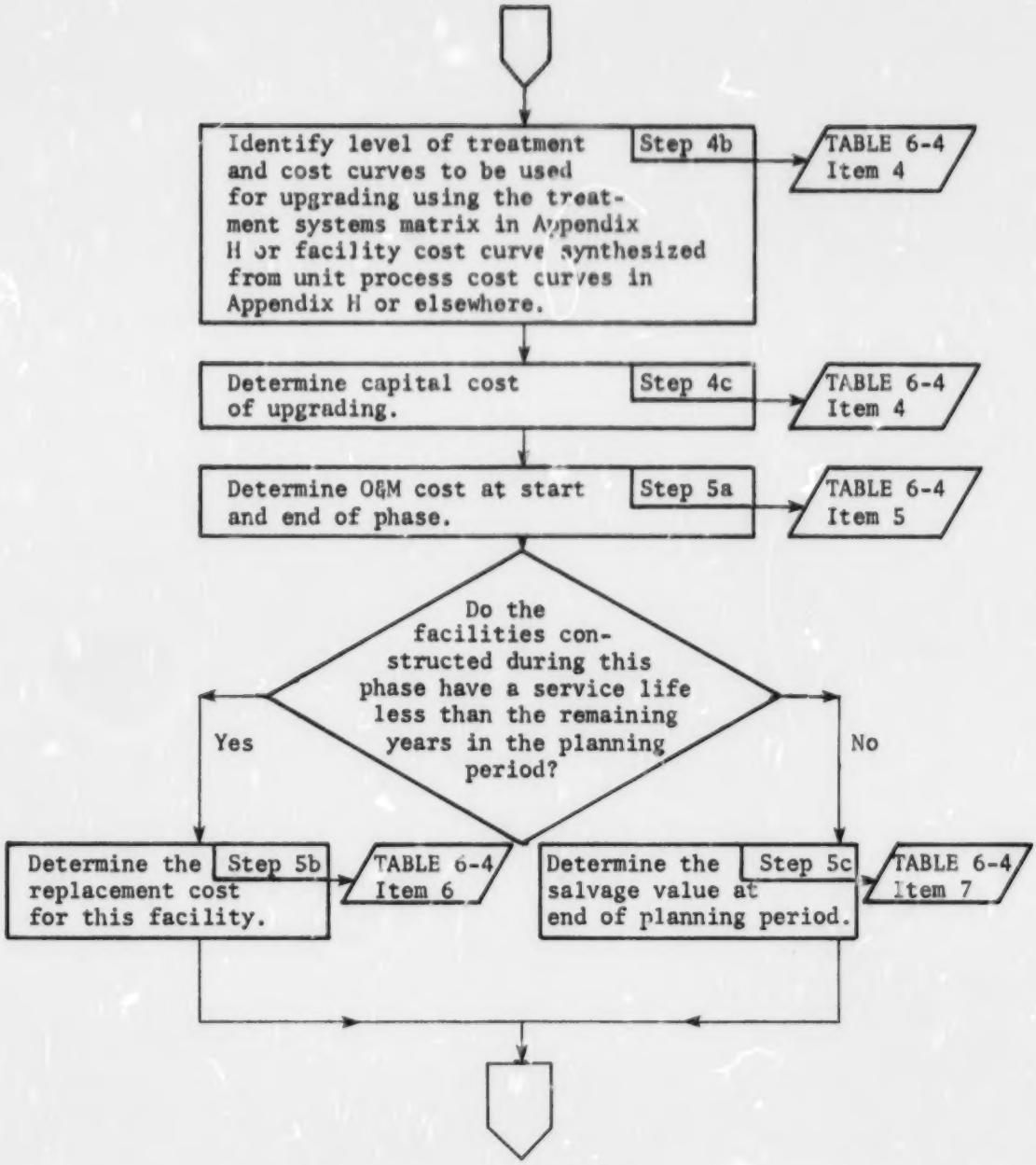

Identify level of treatment and cost curves to be used for upgrading using the treatment systems matrix in Appendix H or facility cost curve synthesized from unit process cost curves in Appendix H or elsewhere.
Step 4b
TABLE 6-4 Item 4
Determine capital cost of upgrading.
Step 4c
TABLE 6-4 Item 4
Determine O&M cost at start and end of phase.
Step 5a
TABLE 6-4 Item 5
Do the facilities constructed during this phase have a service life less than the remaining years in the planning period?
Yes
No
Determine the replacement cost for this facility.
Step 5b
TABLE 6-4 Item 6
Determine the salvage value at end of planning period.
Step 5c
TABLE 6-4 Item 7

FIGURE 6-10 (CONTINUED)

TREATMENT FACILITY METHODOLOGY
FLOWCHART

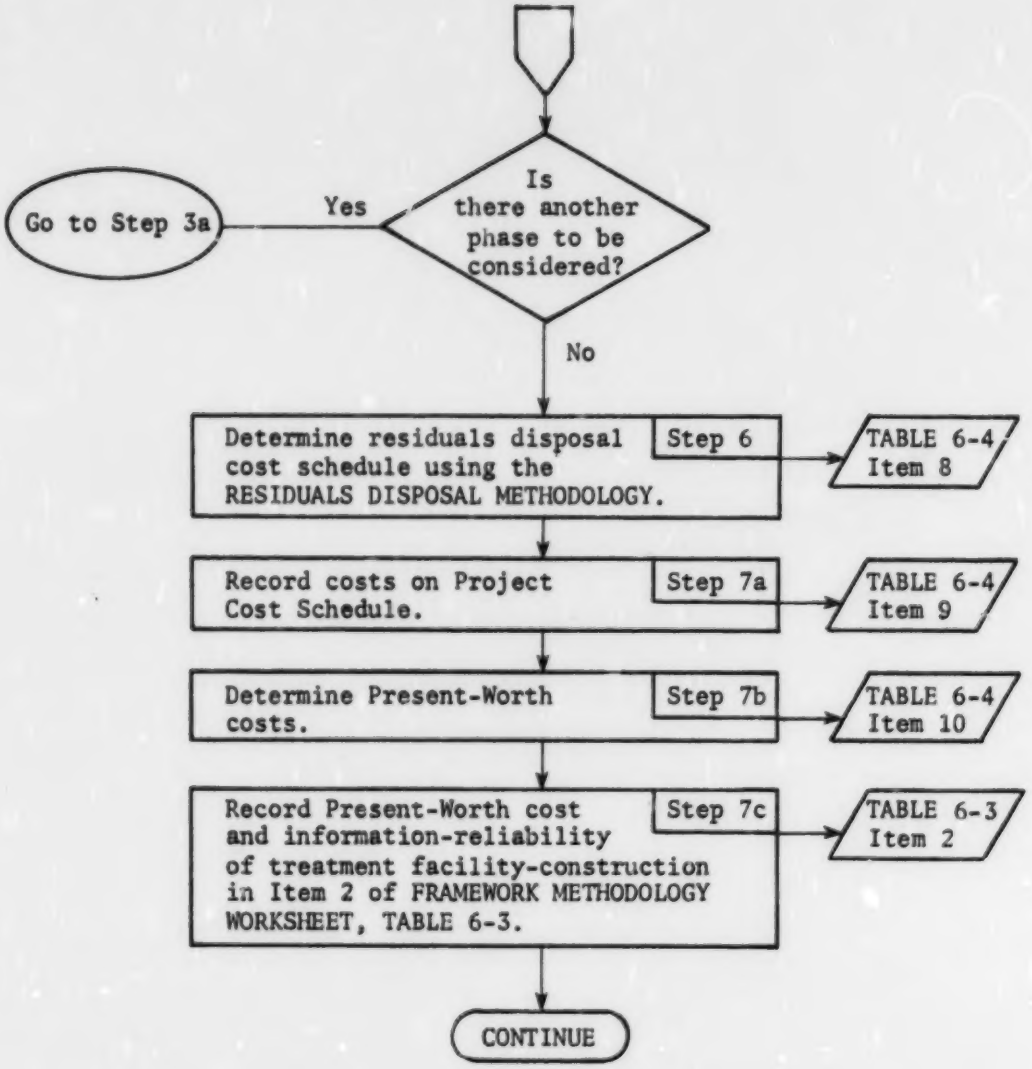

Is there another phase to be considered?
Yes
Go to Step 3a
No
Determine residuals disposal cost schedule using the RESIDUALS DISPOSAL METHODOLOGY.
Step 6
TABLE 6-4 Item 8
Record costs on Project Cost Schedule.
Step 7a
TABLE 6-4 Item 9
Determine Present-Worth costs.
Step 7b
TABLE 6-4 Item 10
Record Present-Worth cost and information-reliability of treatment facility-construction in Item 2 of FRAMEWORK METHODOLOGY WORKSHEET, TABLE 6-3.
Step 7c
TABLE 6-3 Item 2
CONTINUE

TABLE 6-4
TREATMENT FACILITY METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgments presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach available (or even as the preferred approach). However, any approaches used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other EPA, State, and local guidelines and regulations.

Item 1 - Program Implementation Schedule.

i. Planning Period: 20 years

ii. Construction phases: _____

Phase	Timing		Flow Projection (mgd)		Design Flow (mgd)
	Year	to Year	Start	End	
1*	Present	to _____	_____	_____	_____
2	_____	to _____	_____	_____	_____
3	_____	to _____	_____	_____	_____
4	_____	to _____	_____	_____	_____
n	_____	to _____	_____	_____	_____

*Existing facility not utilized at full capacity.

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TABLE 6-4 (continued)
TREATMENT FACILITY METHODOLOGY
WORKSHEET

iii. Treatment Objectives.

Note: Dissolved oxygen deficits use ultimate oxygen demand inputs (Table 6-3). These must be reconverted back to CBOD and NBOD (NH_3) concentrations to determine discharge limitations (See Appendix H discussion of Treatment Systems Performance Matrix).

	Effluent Quality								
Phase	Reference Cost Curve**	BOD mg/l	COD mg/l	TSS mg/l	T-P mg/l	NH_3-N mg/l	NO_3-N mg/l	T-N mg/l	T-C #/100ml
Existing Facility									
1									
2									
3									
n									

**Treatment System curve number (Appendix H, Figures H-2 to H-15) or reference number for synthesized system cost curve developed from unit process curves (Appendix H).

iv. Existing Facility Characteristics.

Design Capacity: _____mgd

Service Life: _____years

Years in Service: _____years

Remaining Service: _____years

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TABLE 6-4 (CONTINUED)
TREATMENT FACILITY METHODOLOGY
WORKSHEET

Item 2 - Existing Facility Cost.
Note: For the first phase of new facility construction, Items 2i, 2ii, and 2iii will equal zero since there is no existing facility.

i. Capital Value (i.e., construction cost plus add-ons).

a. Design Q = _____ mgd

b. Level of Treatment: Reference Cost Curve _____
Service Life _____

c. Construction Cost (Curve $) = _____

d. plus Piping - Curve $ x 15% = _____
Electrical - Curve $ x 12% = _____
Instrumentation - Curve $ x 8% = _____
Site Preparation - Curve $ x 5% = _____
Miscellaneous Structures = _____

e. Sub-Total 1, Construction Cost (c+d) _____

f. plus Sub-Total 1 x Engineering and Construction 15% = _____
Sub-Total 1 x Contingencies 15% = _____
_____

g. Sub-Total 2: Capital Cost (e+f) _____

h. CAPITAL VALUE OF EXISTING FACILITY = Sub-Total 2 x $\frac{\text{ENR (Current)}}{2475^*}$ = _____
* ENR = 2475, September, 1976.

ii. Replacement Cost.
(compute only if planning period is greater than remaining service life)

$$\text{Replacement Cost} = \frac{\text{Planning Period - Remaining Service Life}}{\text{Planning Period}} \times \text{Capital Value}$$

= _____ at year _____

iii. Salvage Value.
(compute only if remaining service life is greater than planning period)

$$\text{Salvage Value} = \frac{\text{Remaining Service - Years to Planning End}}{\text{Remaining Service}} \times \text{Capital Value}$$

= _____ at end of planning period.

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TABLE 6-4 (CONTINUED)
TREATMENT FACILITY METHODOLOGY
WORKSHEET

Item 3 - Expansion Program or New Facility Construction.

Phase Number _____

i. Existing Capacity = _____ mgd (previous phase or existing facility; zero if new facility)

ii. Expanded or New Facility Capacity = _____ mgd (design capacity of next phase)

iii. Level of Treatment: Reference Cost Curve _____
Service Life _____

iv. Construction cost of expanded or new facility - enter cost curve at expanded or new facility at capacity (ii) _____

v. Construction cost of existing facility - enter cost curve at existing facility at capacity (i) _____

vi. Sub-Total 1: Expanded or New Facility Construction Cost (iv-v) = _____

vii. plus Sub-Total 1 x Piping 15% = _____
Sub-Total 1 x Electrical 12% = _____
Sub-Total 1 x Instrumentation 8% = _____
Sub-Total 1 x Site Preparation 5% = _____

viii. Sub-Total 2: Construction Cost (vi + vii) _____

ix. plus Sub-Total 2 x Expansion/Upgrading Factor____ = _____
Sub-Total 2 x Engineering and Construction 15% = _____
Sub-Total 2 x Contingencies 15% = _____

x. Sub-Total 3: Capital Cost (viii + ix) _____

xi. CAPITAL COST OF EXPANSION OR NEW FACILITY = Sub-Total 3 x $\frac{\text{ENR (Current)}}{2475^*}$ = _____

* ENR (Engineering News Record) = 2475, September, 1976.

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TABLE 6-4 (CONTINUED)
TREATMENT FACILITY METHODOLOGY
WORKSHEET

Item 4 - Upgrading Program.

Phase Number _____

i. Existing Level of Treatment: Reference Cost Curve _____
(previous phase or existing facility)

ii. Required Level of Treatment: Reference Cost Curve _____
(for the identified phase) Service Life _____

iii. Q = _____ mgd (design capacity)

iv. Construction Cost at required level of treatment - curve from ii _____

v. Construction Cost at existing level of treatment - curve from i _____

vi. Sub-Total 1: Construction Cost of Upgrading (iv-v) = _____

vii. plus Sub-Total 1 x Piping 15% = _____
Sub-Total 1 x Electrical 12% = _____
Sub-Total 1 x Instrumentation 8% = _____
Sub-Total 1 x Site Preparation 5% = _____

viii. Sub-Total 2: Construction Cost (vi + vii) _____

ix. plus Sub-Total 2 x Expansion/Upgrading Factor___ = _____
Sub-Total 2 x Engineering and Construction 15% = _____
Sub-Total 2 x Contingencies 15% = _____

x. Sub-Total 3: Capital Cost (viii + ix) _____

xi. CAPITAL COST OF UPGRADING = Sub-Total 3 x $\frac{\text{ENR (Current)}}{2475^*}$ = _____

* ENR = 2475, September, 1976.

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TABLE 6-4 (CONTINUED)
TREATMENT FACILITY METHODOLOGY
WORKSHEET

Item 5 - O&M Constant and Variable Cost.

Phase _____

Level of Treatment: Reference Cost Curve _____

Timing		Design Flow		O&M Cost	
Start (yr.)	End (yr.)	Start (mgd)	End (mgd)	Start	End
___	___	___	___	$___	$___

Item 6 - Phase ___ Replacement Costs (Upgraded and/or Expanded Portion)
(Compute if planning period is greater than phase service life)
Replacement Cost Schedule.

Expansion		Upgrading		Total	
Year	Cost	Year	Cost	Year	Cost
___	___	___	___	___	___
___	___	___	___	___	___

Replacement Cost for Phase___ =

$$\frac{\text{Years from Time of Replacement to End of Planning Period}}{\text{Service Life}} \text{ X Capital}$$

Item 7 - Phase ___ Salvage Value at End of Planning Period.
(Compute if phase service life is greater than years to planning period end)

$$\text{Salvage Value} = \frac{\text{(Service Life - Years to Planning End)}}{\text{Service Life}} \text{ x Capital}$$

Expansion S.V. = $_____

Upgrading S.V. = $_____

Total Phase S.V. $_____

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TABLE 6-4 (CONTINUED)
TREATMENT FACILITY METHODOLOGY
WORKSHEET

Item 8 - Residual Disposal Cost, using RESIDUALS DISPOSAL METHODOLOGY.

i. Residual Disposal Technique.

Solids Nature _____

Residual Type _____

Disposal Method _____

Transportation _____

ii. Residual Disposal Cost Schedule.

Phase	Timing Yr. to Yr.		Capital	O&M Start	O&M End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Land Cost								
1								
2								
3								
n								

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TABLE 6-4 (CONTINUED)
TREATMENT FACILITY METHODOLOGY
WORKSHEET

Item 9 - Project Cost Schedule (Summary of costs developed in TREATMENT FACILITY METHODOLOGY).

Phase	Year to Year	Item No.	Capital Cost	Start O&M	End O&M	Variable O&M	Salvage Value
1		3 (Expand/New) 4 (Upgrade 5/6/7 8 (Residual)					
	Total Phase 1						
2		3 (Expand/New) 4 (Upgrade) 5/6/7 8 (Residuals)					
	Total Phase 2						
3		3 (Expand/New) 4 Upgrade) 5/6/7 8 (Residuals)					
	Total Phase 3						
n		3 (Expand/New) 4 (Upgrade) 5/6/7 8 (Residuals)					
	Total Phase n						

Replacement Schedule

Year ____ Cost ____

Item 10 - Present-Worth Cost, using PRESENT-WORTH METHODOLOGY

Interest _____% (from Water Resources Council 18 CFR 704.39, Discount Rate, published annually)

Present-Worth Cost $_____

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Notes on Methodology Logic

Step 1a (Item 1i) - This step identifies the program implementation schedule. The flow projection represents the anticipated wastewater flow at the beginning and end of each phase. The design flow, however, represents the desired treatment facility capacity to be provided for the duration of the phase. Therefore, facility construction costs are defined by an increase in the design flow, while the gradual increase of O&M costs will be identified by the flow projection.

Step 1b (Item 1ii) - This step identifies the treatment objectives to be met during the various phases of construction throughout the planning period. Included are design flows and effluent characteristics for each of the phases. Also identified are the cost curves applicable to the identified treatment levels which can be either the systems curves included in Appendix H, a special curve synthesized from the unit process cost curves, or other acceptable cost curves. The condition of the existing facility is identified in terms of effluent characteristics and useful life (remaining service life).

Step 2a (Item 2i) - This step determines the value of the existing treatment facility, using the cost-curve information in Appendix H. This information is adjusted to reflect installed costs based on the identified percentage factors or on better information (e.g., site-specific data) the user may possess. The capital value does not actually represent the Present-Worth of the existing facility because it is not adjusted for the remaining service life. However, the capital value does represent the cost to build the existing facility under present conditions, and is useful in defining the phase out cost, replacement cost, or salvage value.

Step 2b (Item 2ii) - This step identifies the replacement cost associated with an existing facility which is utilized in the project but which has a remaining service life shorter than the planning period. This computation assumes that the replacement cost is a lump sum that occurs at the end of the service life and has no salvage value at the end of the planning period.

Step 2c (Item 2iii) - This step identifies the salvage value at the end of the planning period when the existing facility is utilized and has a remaining (current) service life that exceeds the planning period. This service life can be identified using the information presented in Appendix H for the treatment systems or by another acceptable method.

Step 3a (Item 3) - In this step, a project phase is considered for detailed cost evaluation. Note that Steps 3a through 5c (Items 3 to 7) will be repeated for each project phase.

Step 3b (Item 3) - This step determines the construction cost for a new facility included in the phase under construction. The times in Worksheet Item 3 pertaining to the value of existing facilities and the upgrade/expansion factor are not relevant for new facilities and should be set to zero.

Step 3c (Item 3) - No discussion.

Step 3d (Item 3) - In this step, the phases that include a treatment-plant expansion are identified by the desired increase in capacity and the level of treatment for the expansion.

Step 3e (Item 3) - In this step, the construction cost associated with the expansion is determined using the Appendix H cost curves or an equivalent synthesized curve and the identified construction factors. The upgrading/expansion factor in Appendix H, Figure H-1, or equivalent, can be utilized, when necessary, to refine this cost estimate to reflect the costs associated with construction which adjoins existing structures.

Step 4a (Item 4) - No discussion.

Step 4b (Item 4) - In this step, the project phases that include upgrading of a treatment facility are identified by the old (previous phase) treatment level and the desired (upgraded) treatment level.

Step 4c (Item 4) - In this step, the cost associated with a treatment upgrading is determined using the cost curves in Appendix H and the identified construction factors. The upgrading/expansion factor can be included,

if necessary, to reflect the costs associated with construction which adjoins existing structures.

Step 5a (Item 5) - In this step, the O&M costs are identified for the phase. Since, in general, the wastewater flow will increase during the phase under consideration, the time pattern of O&M costs has been approximated by considering constant and variable O&M costs. The constant O&M cost will be incurred throughout the phase and will be determined by the initial flow rate. The variable O&M reflects the flow increase and is computed by multiplying the average increase in the annual O&M cost during the phase

$$\frac{\text{Final O\&M Cost - Initial O\&M Cost}}{\text{Elapsed Years}}$$

by the gradient series present-worth factor, which is described in the PRESENT-WORTH METHODOLOGY. The required O&M costs are included in the systems curves in Appendix H or can be developed using the process curves or their equivalent.

Step 5b (Item 6) - This step is used to identify the replacement cost schedule for the upgraded or expanded facilities. These values are developed for facilities having a service life shorter than the years remaining in the planning period.

Step 5c (Item 7) - This step identifies the salvage value for the upgraded or expanded facilities. This is computed for the expansion/upgrading or new facilities for each phase, with the total project salvage value then computed from the sum of the salvage values identified for the facilities constructed during each phase.

Step 6 (Item 8) - This step identifies the residual-disposal technique, involving nature of solids, types of residuals, disposal method, and transportation. This item also includes a residual-disposal cost schedule. It is important to note that the RESIDUALS DISPOSAL METHODOLOGY and TRANSPORTATION COST METHODOLOGY will be used to develop the cost schedule in Item 8.

Step 7 (Item 9) - The project cost schedule for each alternative is summarized in this step. A phase-by-phase schedule allows orderly consolidation

of the cost values determined throughout this methodology. The item and number indicated on this schedule correspond to the item numbers of the TREATMENT FACILITY METHODOLOGY. It will generally be easiest to combine the identified start and end O&M costs (e.g., expansion plus residuals) and compute the variable O&M costs for each phase by the method outlined in Step 5a. The data in this schedule are utilized in the PRESENT-WORTH METHODOLOGY.

Step 9a (Item 10) - This step records the interest rate and the computed Present-Worth of the alternative. The present worth should also be entered on the FRAMEWORK METHODOLOGY Worksheet.

6.4.2.4 Land Application Methodology

Discussion

Although land application of a treated wastewater effluent can take many forms, this methodology is designed to evaluate two types of systems: 1) the underdrained spray irrigation site which involves a point source discharge of the treated effluent; and 2) the undrained spray irrigation site. The former would serve as a treatment system and might be evaluated as an alternative to existing or additional wastewater treatment unit processes. The latter case would actually describe a disposal technique and might have the added benefit of groundwater recharge or no discharge of pollutants to the receiving stream.

Design criteria to be considered when selecting potential sites and, in particular, when evaluating a specific disposal site, are well documented in EPA guidance documents on land application systems. See references (14) through (18). The criteria for identifying potential sites should be developed for the specific areas of interest. The following items, while not all inclusive, should be addressed during site identification:

- Land use patterns (e.g., land use restrictions, buffer zones).
- Socio-economic impacts (e.g., density of dwellings and other structures, health risks, and traffic patterns).
- Physical characteristics of the site (e.g., soil groups, topography, geologic conditions, ground-water conditions).
- Restricted areas (e.g., historical sites, sensitive environmental areas).

It is advisable in the identification of potential sites to establish the evaluation criteria in conjunction with local officials; this will insure that local concerns are properly considered.

The LAND APPLICATION METHODOLOGY describes the evaluation process for a particular land-application/point-source combination. Factors that are considered in this evaluation include the water quality impact of the land disposal alternative, the wastewater transportation cost, and the land application site cost. The methodology computes these costs for several alternative land application sites.

It is assumed that all wastewater flow from the point source is applied to the land application site being evaluated. However, the methodology logic could be readily modified by the user to handle specific situations where wastewater from one point source is sent to several sites, or where only a portion of the point source discharge is sent to a land-application site.

Finally, the user should be aware that much of the information, particularly with respect to potential land-application sites, should be readily available from earlier evaluations for the planning area. The user should utilize any such existing data to simplify the evaluation process.

Methodology Logic

A summary of the logic of the LAND APPLICATION METHODOLOGY is presented in Figure 6-11. An expanded flowchart, Figure 6-12, lists the steps to be taken in determining performance and costs. The worksheets for recording the operations are presented as Table 6-5. Notes concerning the methodology steps and worksheet items are presented after the worksheets.

FIGURE 6-11

LAND APPLICATION METHODOLOGY
LOGIC SUMMARY

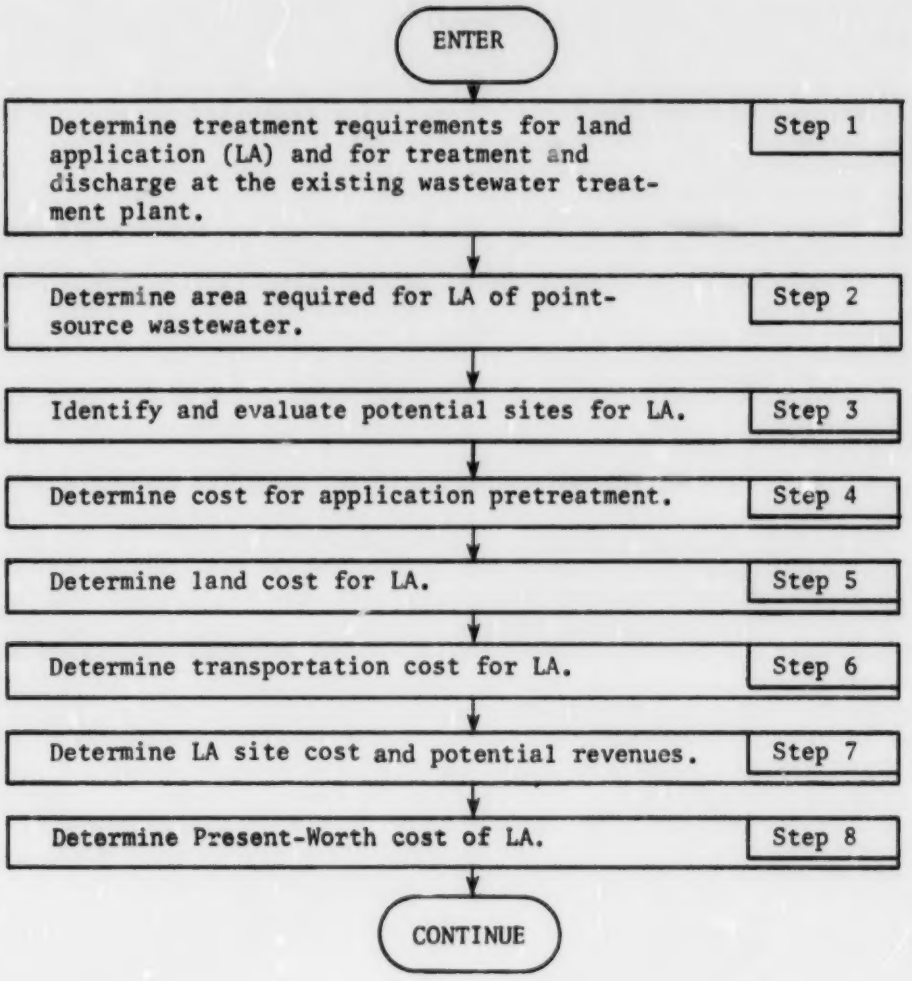
ENTER
Determine treatment requirements for land application (LA) and for treatment and discharge at the existing wastewater treatment plant.
Step 1
Determine area required for LA of point-source wastewater.
Step 2
Identify and evaluate potential sites for LA.
Step 3
Determine cost for application pretreatment.
Step 4
Determine land cost for LA.
Step 5
Determine transportation cost for LA.
Step 6
Determine LA site cost and potential revenues.
Step 7
Determine Present-Worth cost of LA.
Step 8
CONTINUE

FIGURE 6-12

LAND APPLICATION METHODOLOGY
FLOWCHART

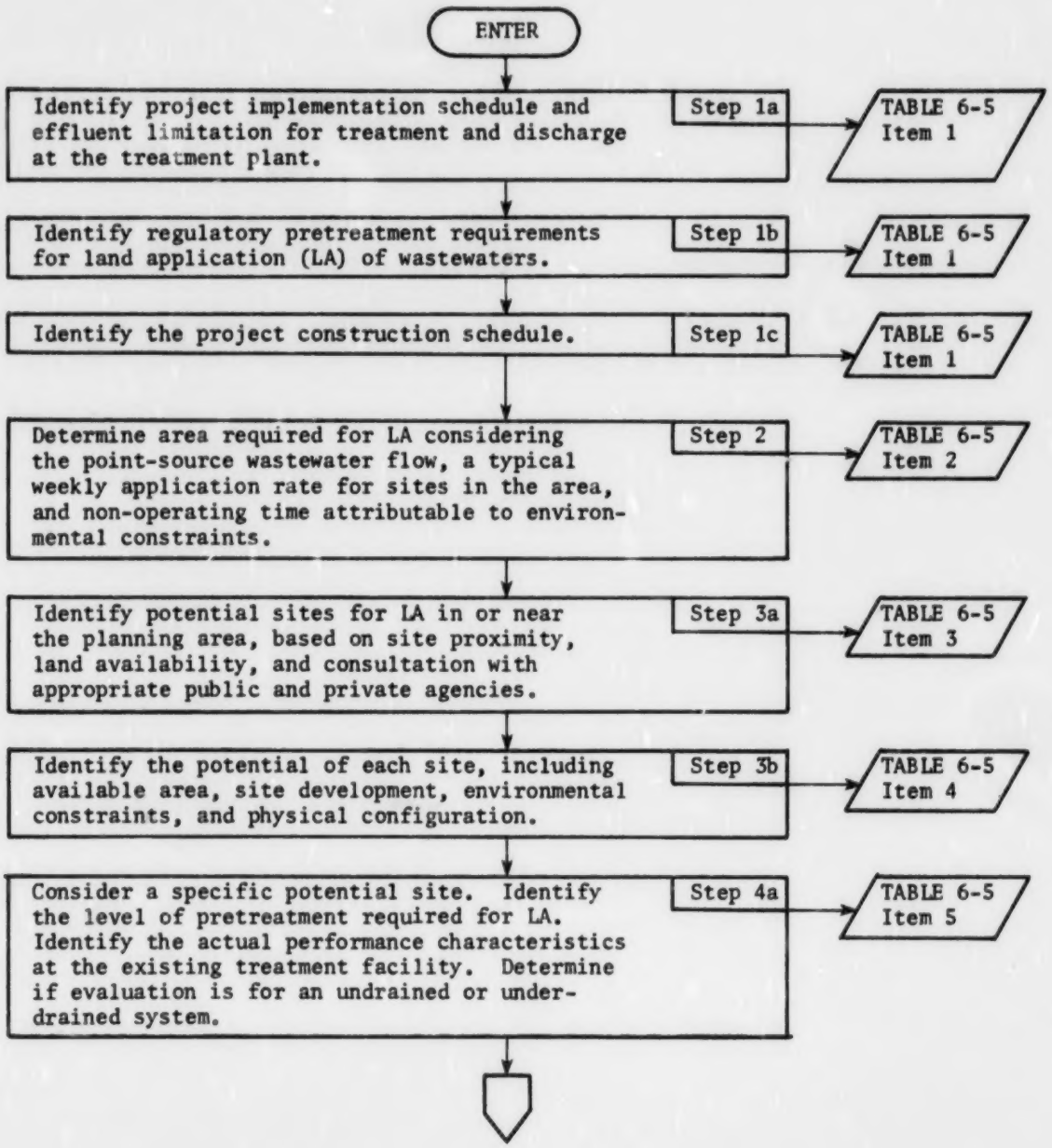
ENTER
Identify project implementation schedule and effluent limitation for treatment and discharge at the treatment plant.
Step 1a
TABLE 6-5 Item 1
Identify regulatory pretreatment requirements for land application (LA) of wastewaters.
Step 1b
TABLE 6-5 Item 1
Identify the project construction schedule.
Step 1c
TABLE 6-5 Item 1
Determine area required for LA considering the point-source wastewater flow, a typical weekly application rate for sites in the area, and non-operating time attributable to environmental constraints.
Step 2
TABLE 6-5 Item 2
Identify potential sites for LA in or near the planning area, based on site proximity, land availability, and consultation with appropriate public and private agencies.
Step 3a
TABLE 6-5 Item 3
Identify the potential of each site, including available area, site development, environmental constraints, and physical configuration.
Step 3b
TABLE 6-5 Item 4
Consider a specific potential site. Identify the level of pretreatment required for LA. Identify the actual performance characteristics at the existing treatment facility. Determine if evaluation is for an undrained or underdrained system.
Step 4a
TABLE 6-5 Item 5

FIGURE 6-12 (CONTINUED)

LAND APPLICATION METHODOLOGY
FLOWCHART

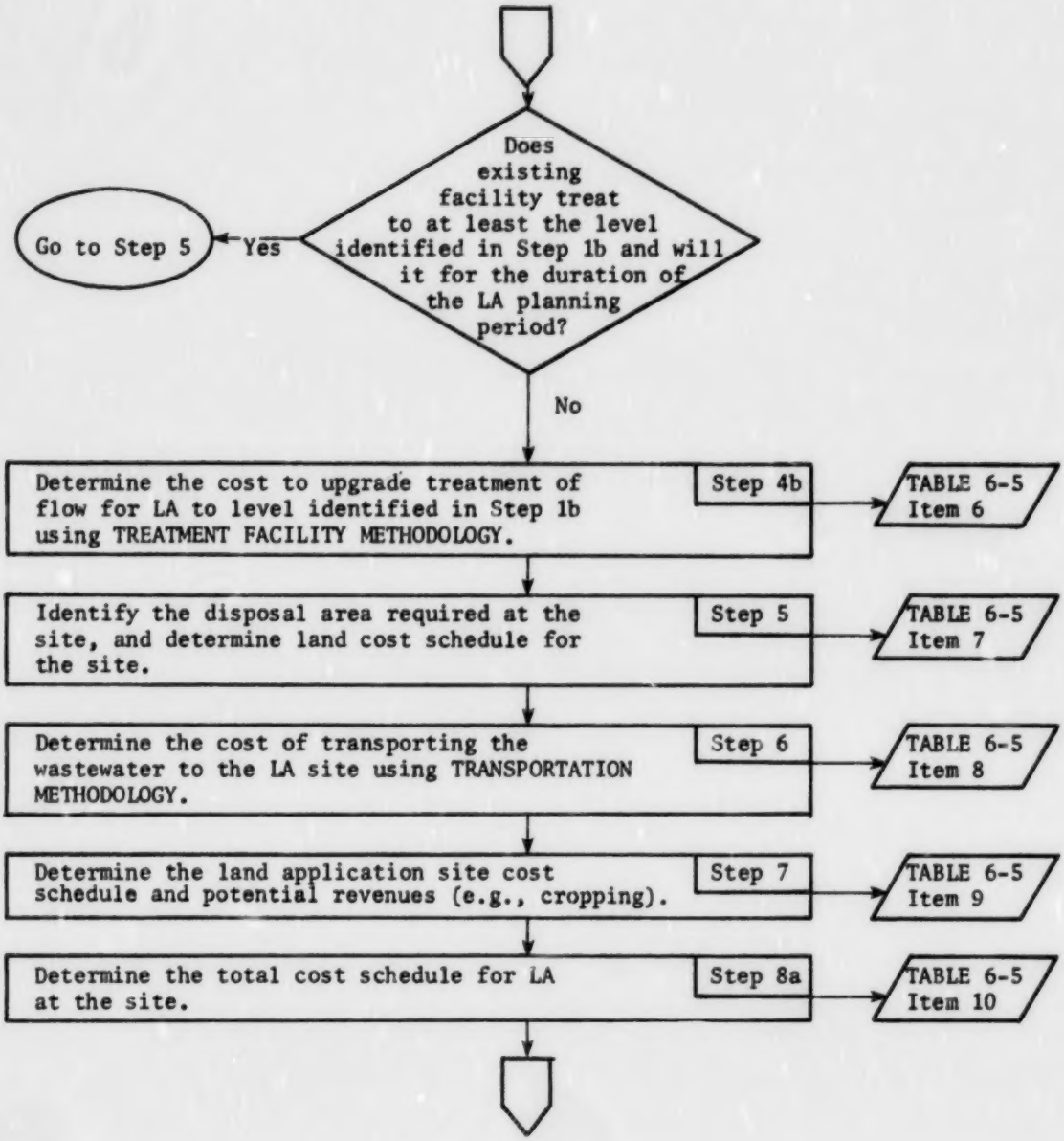
Does existing facility treat to at least the level identified in Step 1b and will it for the duration of the LA planning period?
Yes
Go to Step 5
No
Determine the cost to upgrade treatment of flow for LA to level identified in Step 1b using TREATMENT FACILITY METHODOLOGY.
Step 4b
TABLE 6-5 Item 6
Identify the disposal area required at the site, and determine land cost schedule for the site.
Step 5
TABLE 6-5 Item 7
Determine the cost of transporting the wastewater to the LA site using TRANSPORTATION METHODOLOGY.
Step 6
TABLE 6-5 Item 8
Determine the land application site cost schedule and potential revenues (e.g., cropping).
Step 7
TABLE 6-5 Item 9
Determine the total cost schedule for LA at the site.
Step 8a
TABLE 6-5 Item 10

FIGURE 6-12 (CONTINUED)

LAND APPLICATION METHODOLOGY
FLOWCHART

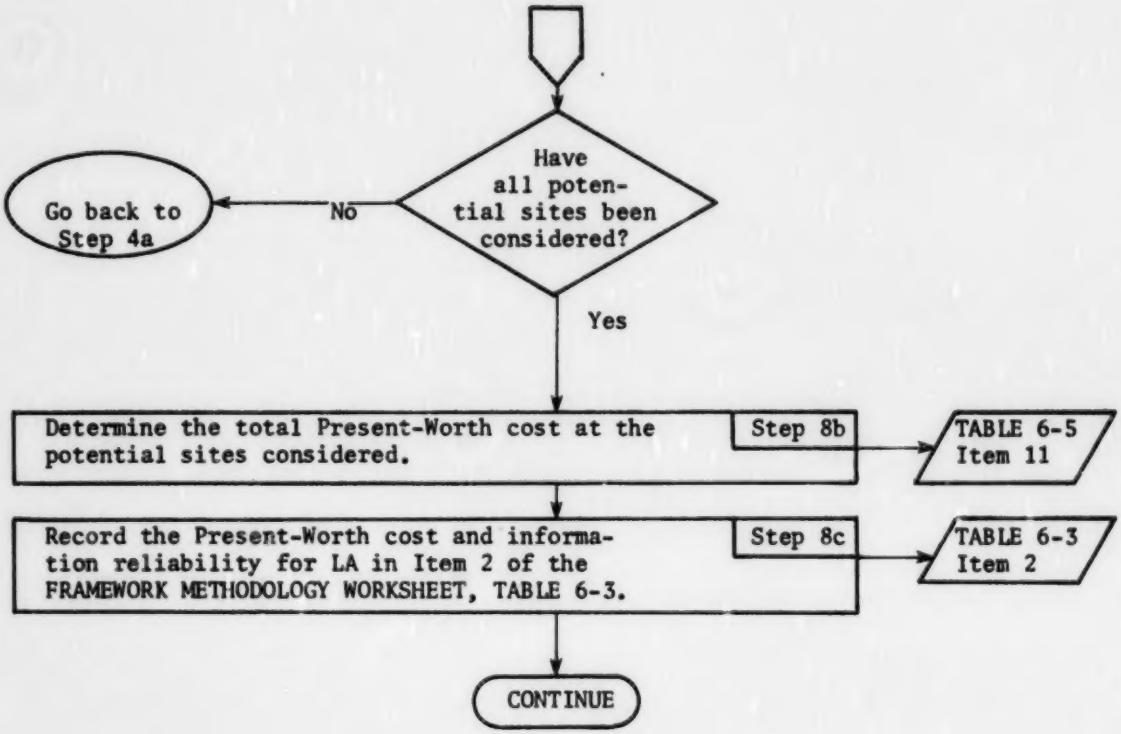
Have all potential sites been considered?
No
Go back to Step 4a
Yes
Determine the total Present-Worth cost at the potential sites considered.
Step 8b
TABLE 6-5 Item 11
Record the Present-Worth cost and information reliability for LA in Item 2 of the FRAMEWORK METHODOLOGY WORKSHEET, TABLE 6-3.
Step 8c
TABLE 6-3 Item 2
CONTINUE

TABLE 6-5

LAND APPLICATION METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgments presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach available (or even as the preferred approach). However, any approach used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other EPA, State, and local guidelines and regulations.

PROJECT SCHEDULE

Item 1 - Program Implementation Schedule.

i. Planning Period: 20 years

ii. Existing Facility Conditions.

Design Capacity: _____ mgd
Years of Service: _____ years
Remaining Service: _____ years

iii. Treatment Levels.

Note: Dissolved oxygen deficits use ultimate oxygen demand inputs (Table 6-3). These must be reconverted back to CBOD and NBOD (NH_3) concentrations in order to determine discharge limitations (See Appendix H discussion of Treatment Systems Performance Ratios).

Level	Reference Cost Curve	Parameter Control Levels							
		BOD mg/l	COD mg/l	TSS mg/l	T-P mg/l	NH_3-N mg/l	NO_3-N mg/l	T-N mg/l	T-C #/100ml
Existing Facility									
Pretreatment									
Discharge Limitations									

iv. Construction Phases: _____

Phase	Timing Year to Year	Design Flow (mgd) Flow Projection Start	Flow Projection End	Pretreatment Start	Pretreatment End	Transportation	Site Start	Site End
1								
2								
3								
n								

By _____ Date _____ Strategy No. _____
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Remarks: _____ Page _____

TABLE 6-5 (CONTINUED)
LAND APPLICATION METHODOLOGY
WORKSHEET

GENERAL SITE EVALUATION

Item 2 - Land Application Ultimate Area Requirement.

i. Maximum Annual Flow Rate at end of Planning Period = _____mgd

ii. Application Rate[1] = _____in./week

iii. Non-operating time = _____weeks/year

iv. Area Required = _____acres, without buffer zone (includes area for roads, buildings, etc.)

Gross Area Required (with 200 ft buffer zone)[2] = _____acres

(Use Nomograph "Total Land Requirement", Figure 6-13, or equivalent)

[1]Items 2ii and 2iii can be used for determining maximum capacity for potential LA sites in Item 5.

[2]Use a more stringent buffer zone limitation if indicated by applicable Federal, State, or local regulations or site conditions.

By _____ Date _____ Strategy No. _____
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TABLE 6-5 (CONTINUED)
LAND APPLICATION METHODOLOGY
WORKSHEET

Item 3 - Potential LA Sites - Location.

(Attach USGS Quad Sheet or equivalent with potential sites outlined and identified.)

By _____ Date _____ Strategy No. _____
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TABLE 6-5 (CONTINUED)
LAND APPLICATION METHODOLOGY
WORKSHEET

Item 4 - Potential LA Sites Data Sheet. (Sample of factors to be considered. This is not an inclusive list; see LA references for additional considerations.)

Site	Approximate Available area (acres)	Estimated treatment capacity (mgd)	Area of site presently irrigated (percent)	Distance from plant (feet)	Elevation difference from plant (feet)	Homes onsite (No.)	Other buildings onsite (No.)	Roads onsite (miles)	Comments-Major problems or advantages

By _____ Date _____ Strategy No. _____
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TABLE 6-5 (CONTINUED)
LAND APPLICATION METHODOLOGY
WORKSHEET

SPECIFIC SITE EVALUATION
SITE _____

Item 5 - Site Implementation Schedule.

i. Planning Period: 20 years

ii. Construction Phases: _____
(If different from Project Schedule, then describe.)

iii. Pretreatment Requirements: Reference Cost Curve _____
(If different from Project Schedule, then describe.)

iv. Performance Characteristics - existing facility: Reference Cost Curve _____ (From Item 1iii)

Item 6 - Pre-application Treatment Cost.

i. Use Treatment Facility Methodology.

Phase	Timing Yr. to Yr.		Capital	O&M Start	O&M End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Existing Facility								
1								
2								
3								
n								

Item 7 - Land Cost.

Application Rate = _____ in./week
Curve Rate = _____ in./week
Factor = Application Rate/Curve Rate = _____

Phase	Design[1] Flow	Adjusted[2] Flow	Land Cost	Salvage Value
1				
2				
3				
n				

[1]Design Flow is the desired application site daily capacity addition for the project Phase.
[2]Adjusted Flow = Design Flow x Factor

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
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TABLE 6-5 (CONTINUED)
LAND APPLICATION METHODOLOGY
WORKSHEET

Item 8 - Transportation Cost.

i. Use Table 6-18, TRANSPORTATION COST METHODOLOGY to complete following schedule:

Phase	Capital	O&M		Salvage Value
		Start	End	
1				
2				
3				
n				

Replacement Schedule

Year	Cost

Item 9 - Application Site Costs.

i. Use cost curve in Appendix H, Figure H-16, or equivalent method:
Curve No. _____
Service Life _____

Phase	Timing	Flow Rate, mgd		Design, mgd	Capital Cost	O&M		Salvage[2] Value	Revenue[3]	
	Yr to Yr	Start	End			Start	End		Start	End
1										
2										
3										
n										

Replacement Schedule

Year	Cost

[1]Adjust curve cost to reflect installed cost.
[2]Develop Salvage Value = $\frac{\text{Service Life - Years to Planning End}}{\text{Service Life}}$ x Capital
which reflects the remaining Phase value at the planning period end.
[3]Include crop revenues, etc.

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TABLE 6-5 (CONTINUED)
LAND APPLICATION METHODOLOGY
WORKSHEET

Item 10 - Monetary Cost Evaluation

i. Cost Schedule.

Phase	Timing Yr to Yr	Item	Capital Cost	Start O&M	End O&M	Variable O&M	Salvage Value	Revenues Start	Revenues End
1		#6							
		#7							
		#8							
		#9							
	TOTAL PHASE 1								
2		#6							
		#7							
		#8							
		#9							
	TOTAL PHASE 2								
3		#6							
		#7							
		#8							
		#9							
	TOTAL PHASE 3								

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TABLE 6-5 (CONTINUED)
LAND APPLICATION METHODOLOGY
WORKSHEET

Item 10 - Monetary Cost Evaluation (Continued).

Phase	Timing Yr to Yr	Item	Capital Cost	Start O&M	End O&M	Variable O&M	Salvage Value	Revenues Start	Revenues End
4		#6							
		#7							
		#8							
		#9							
	TOTAL PHASE 4								

Replacement Schedule

Item	Year	Cost

By _____ Date _____ Strategy No. _____
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TABLE 6-5 (CONTINUED)

LAND APPLICATION METHODOLOGY
WORKSHEET

PRESENT-WORTH COST EVALUATION

Item 11 - Present-Worth Cost.

Site	Present-Worth Cost	Reference Sheet

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Notes on Methodology Logic

Step 1a (Item 1i, ii, iii) - The project implementation schedule is developed by considering the projected wastewater quantity estimates for the planning area, existing facilities, state and Federal requirements, and local factors. In many cases, the user will wish to identify a phased program that is identical to that developed for the wastewater treatment facility evaluation, since this will allow a direct comparison of the monetary costs associated with each alternative during each phase. The effluent limitation for treatment and discharge should be available from a previous evaluation; if not, the user can develop the required control level using the water quality impact analysis techniques described in Chapter 5. The required level of treatment can then be determined: from the Treatment System Performance Matrix (Table H-3), from a synthesis of the unit process curves, or their equivalent.

Step 1b (Item 1iii, iv) - In this step, the requirements for land-application pretreatment are defined. The user should identify any regulations concerning the minimum acceptable pretreatment for land application in the planning area. Where appropriate, the characteristics of the land in the planning area should be considered in the determination of the required pretreatment level. In the general case, secondary treatment or equivalent should be considered the minimum that will insure adequate site performance.

Step 1c (Item 1iv) - This step identifies the construction program to be evaluated for the land application alternative. The various aspects of the project (pretreatment, transportation, application site) can have different design flows during the project, since these are evaluated individually. However, each of the individual project considerations should be keyed to the same phase timing to facilitate the development of the project schedule.

Step 2 (Item 2) - The purpose of this step is to identify the area requirements for a land-application site. The factors that should be considered for sites in the planning area include the design flow rate of the wastewater source, the allowable application rate (in terms of applied inches per week), and the required non-operating time. The design flow rate should be determined as an average flow, because storage facilities are usually provided

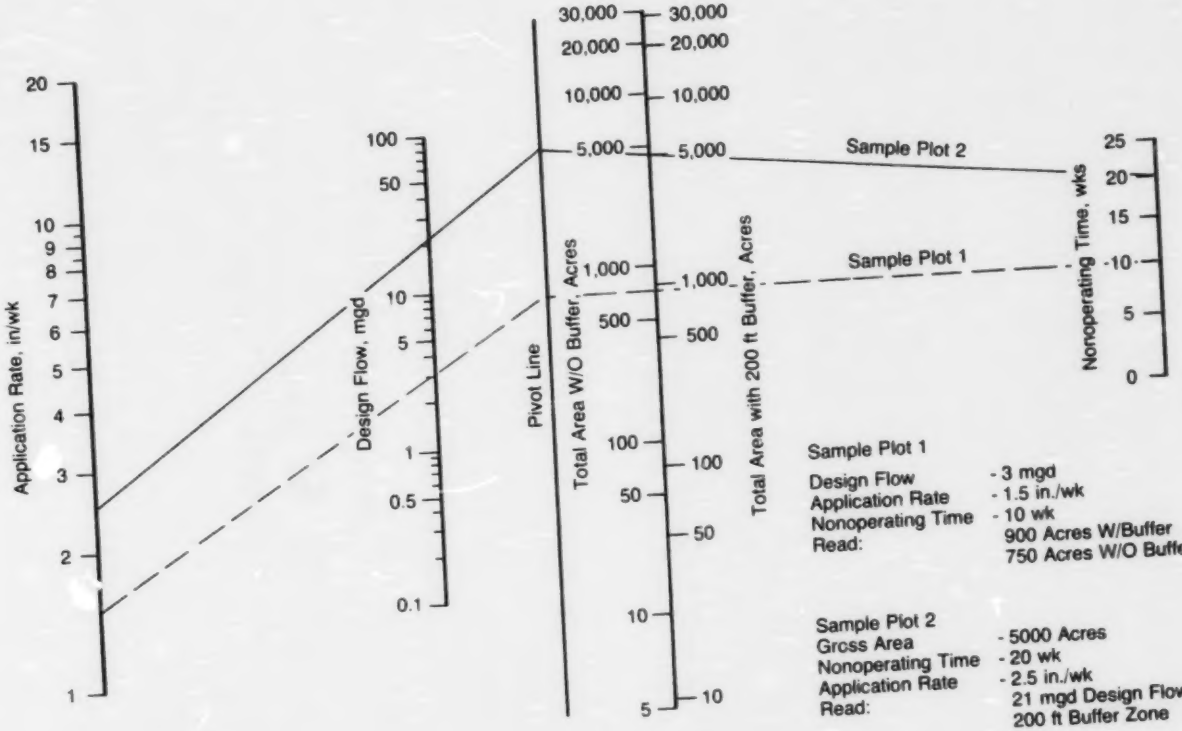
at the land-application site. The user should identify any Federal, state, or local regulations concerning allowable application rates at land-application sites or siting requirements. The user should also consider the allowable application rate at existing land-application sites in the planning area. The non-operating time can be determined by considering the climate in the immediate area.

In addition, the user should identify buffer zone requirements for land application sites, as well as the area required for roads, buildings, and so forth. To assist the user in determining the area required for land application of the wastewater, a nomograph, Figure 6-13, has been provided. The required area, both with and without a buffer zone, should be identified, so that the user can identify the maximum capacity at a potential land-application site.

Step 3a (Item 3) - In this step, potential land-application sites are identified. There are numerous factors to be considered in identifying the site, and these are well documented in EPA guidance documents on land application. Characteristics of the potential sites include proximity to the wastewater source and adequate land availability, and should be evaluated utilizing the recommendations of appropriate public and private agencies. The potential sites should be shown on USGS quad sheets or equivalent topographic maps.

Step 3b (Item 4) - The potential sites identified in the previous step are further evaluated in this step. The maximum wastewater capacity at each site is determined using the nomograph "Total Land Requirement" (Figure 6-13) and the application rate and non-operating time previously identified (Item 2). However, the user can modify these typical numbers for any sites for which they would not be applicable. The additional information requested for each potential site should be available from an accurate topographic map, and should be useful in identifying the most feasible sites for a particular wastewater source.

Step 4a (Item 5) - In this step, one of the potential sites is selected for a cost evaluation. The planning period and project phases are evaluated and described in detail when they are different from the project schedule previously identified in Step 1a (Item 1). The application pretreatment level



Reference: Costs of Wastewater Treatment by Land Application, EPA 430/9-75-003, June 1975

FIGURE 6-13 TOTAL LAND REQUIREMENT

should be identified and the Treatment System Performance Matrix (Table H-3) or a comparable method utilized to determine required treatment levels. The user should identify whether an underdrained or undrained site is to be evaluated based upon the site conditions, results of water quality impact analysis in Chapter 5, and other site-specific factors. If desired, the evaluation could be performed for both types of systems.

Step 4b (Item 6) - In this step, the user will identify the cost schedule for wastewater pretreatment prior to land application, where the existing facility is currently inadequate or will become inadequate (due to increased wastewater flow, etc.) during the planning period. The TREATMENT FACILITY METHODOLOGY should be utilized to develop this cost schedule.

Step 5 (Item 7) - In this step, the user will identify the area required at the disposal site for each project phase. The cost of land can be determined by the user on the basis of the average land cost in the area, which, if necessary, can be obtained from the tax assessor. This step can be eliminated when the total cost curve of Appendix H, Figure H-16, (which includes land cost) is used, but only if the assumptions used to develop that curve are valid for the system.

Step 6 (Item 8) - The cost to relocate the wastewater from the existing discharge point to the proposed land-application site is determined in this step. This can be determined using the TRANSPORTATION COST METHODOLOGY which will identify the pipeline and pumping cost for transporting the wastewater.

Step 7 (Item 9) - In this step, the cost schedule for developing and expanding the land-application site is determined in accordance with the desired project phasing. When evaluating land application as a control alternative, the cost associated with the underdrain system should also be developed for the site. (Note: Figure H-16 in Appendix H is for undrained systems only.) Also, potential revenues should be identified, including cash crops, etc. Although the land-application cost curve includes an assumed storage requirement and land-application rate, the user can modify the capital cost estimate to reflect the conditions at a specific site. In general, this adjustment is proportional to the ratio of the site condition to the design condition. For example, the cost for a 2.5 inch/week application site would be 2.0/2.5 times

the cost described in the construction cost curve, which assumes a 2.0 inch/week rate. The construction cost developed from the curve does not include estimated costs for piping, electrical, instrumentation, construction, engineering, or contingencies; these are figured separately using assumptions in the introduction to Appendix H or site-specific data. Typically, the user can identify these costs using a method similar to that described in the TREATMENT FACILITY METHODOLOGY.

Step 8a (Item 10) - In this step, the cost schedules identified in Steps 4, 5, 6, and 7 (Worksheet Items 6, 7, 8, 9) are combined to represent the project cost schedule of the land-application site.

Step 8b (Item 11) - The Present-Worth cost of this site is then determined using the PRESENT-WORTH METHODOLOGY. Note that revenues represent a negative cost and should be entered into this calculation as such.

6.4.2.5 Land Management Methodology

Discussion

Land management control alternatives have great potential for cost-effective water pollution control. However, the implementation of these control alternatives has been severely hindered because of the lack of information both in regard to documentation of effective performance and in regard to cost. Furthermore, implementation of land management decisions often has an impact on or requires close and continuing interface with local institutions and social customs, and the reactions and/or resistance are difficult to anticipate.

Quantitative data on performance and cost for the few land management control alternatives for which such information is available are included in Appendix G. Additional data on these alternatives and data on other alternatives not currently included in Appendix G will become available when further development of the relatively new field of land management will provide better understanding and documentation of its concepts and applications.

Methodology Logic

A summary of the logic of the LAND MANAGEMENT METHODOLOGY is presented in Figure 6-14. An expanded flowchart, Figure 6-15, lists the steps to be taken in determining performance and cost. The worksheets for recording the operations are presented as Table 6-6. Notes concerning the methodology steps and worksheet items are presented after the worksheets.

FIGURE 6-14

LAND MANAGEMENT METHODOLOGY
LOGIC SUMMARY

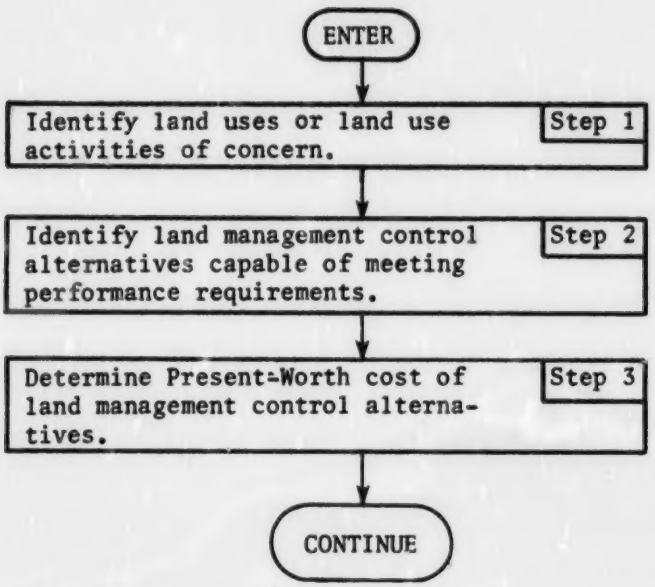

ENTER
Identify land uses or land use activities of concern.
Step 1
Identify land management control alternatives capable of meeting performance requirements.
Step 2
Determine Present-Worth cost of land management control alternatives.
Step 3
CONTINUE

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FIGURE 6-15

LAND MANAGEMENT METHODOLOGY
FLOWCHART

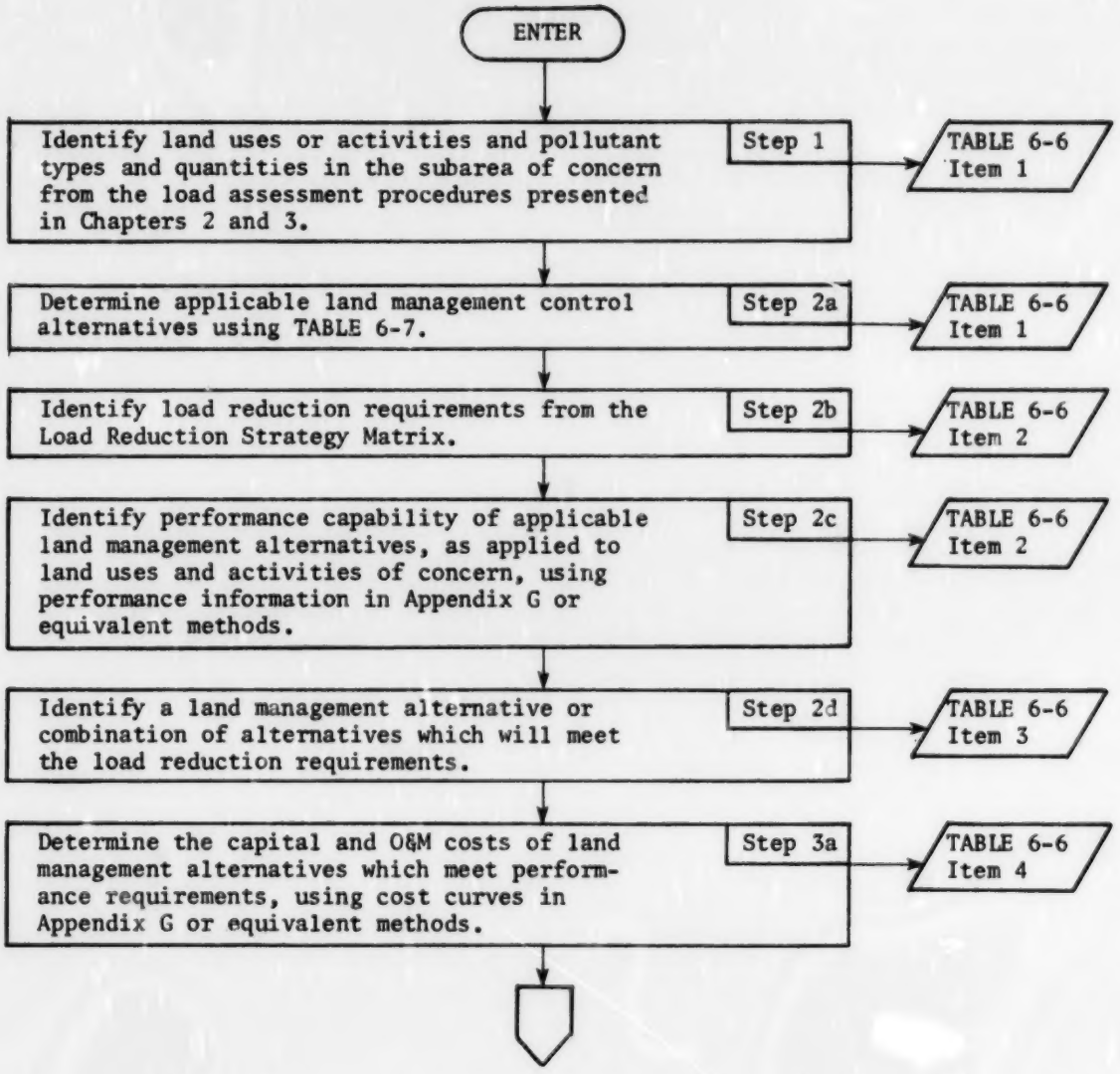
ENTER
Identify land uses or activities and pollutant types and quantities in the subarea of concern from the load assessment procedures presented in Chapters 2 and 3.
Step 1
TABLE 6-6 Item 1
Determine applicable land management control alternatives using TABLE 6-7.
Step 2a
TABLE 6-6 Item 1
Identify load reduction requirements from the Load Reduction Strategy Matrix.
Step 2b
TABLE 6-6 Item 2
Identify performance capability of applicable land management alternatives, as applied to land uses and activities of concern, using performance information in Appendix G or equivalent methods.
Step 2c
TABLE 6-6 Item 2
Identify a land management alternative or combination of alternatives which will meet the load reduction requirements.
Step 2d
TABLE 6-6 Item 3
Determine the capital and O&M costs of land management alternatives which meet performance requirements, using cost curves in Appendix G or equivalent methods.
Step 3a
TABLE 6-6 Item 4

FIGURE 6-15 (CONTINUED)

LAND MANAGEMENT METHODOLOGY
FLOWCHART

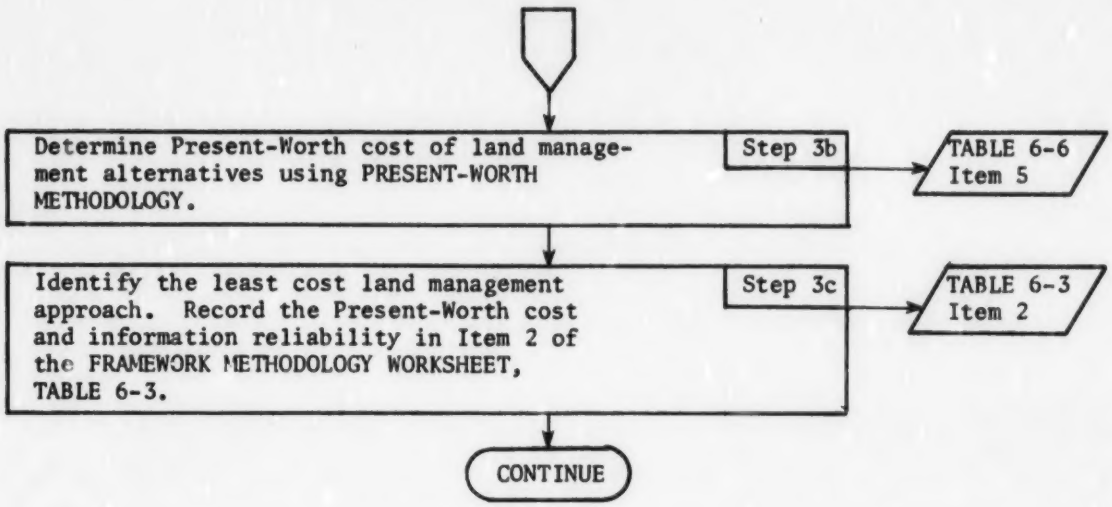
Determine Present-Worth cost of land management alternatives using PRESENT-WORTH METHODOLOGY.
Step 3b
TABLE 6-6 Item 5
Identify the least cost land management approach. Record the Present-Worth cost and information reliability in Item 2 of the FRAMEWORK METHODOLOGY WORKSHEET, TABLE 6-3.
Step 3c
TABLE 6-3 Item 2
CONTINUE

TABLE 6-6
LAND MANAGEMENT METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgements presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach available (or even as the preferred approach). However, any approaches used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other EPA, State, and local guidelines and regulations.

Item 1 Land uses and land use activities of concern.

Land Uses and Land Use Activities[1]	Wasteload BOD5	N	P	TSS	TC[2]	Applicable Land Management Alternatives

Item 2

	Percent Reduction BOD5	N	P	TSS	TC
i) Load reduction requirements:					

ii) Land management alternative performance capability.

Land Uses and Land Use Activities	Applicable Land Management Alternative	Performance Range-Percent Reduction BOD5	N	P	TSS	TC

[1] See Table 6-7.
[2] Most probable number/100 ml

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TABLE 6-6 (continued)
LAND MANAGEMENT METHODOLOGY
WORKSHEET

Item 3 Identification of alternatives which will achieve required reduction.

Land Uses and Land Use Activities	Land Management Alternatives	Parameter	[Waste load] X	[Performance Capa.] =	[Waste-load Red.]

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TABLE 6-6 (continued)
LAND MANAGEMENT METHODOLOGY
WORKSHEET

Item 4 Capital and O&M Cost (From Appendix G).

Land Management Alternative	Affected Land Use/Activity (Acres)	Capital Cost	O&M Cost

Item 5 Present-Worth cost of land management alternatives.

Land Management Alternatives	Present-Worth Cost	Information Reliability[1]	
		Performance	Cost

[1]From Appendix G

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Notes on Methodology Logic

Step 1 - The various land uses and land use activities, and the pollutant loads from these land uses and activities are identified using the Load Assessment Methodology of Chapters 2 and 3.

Step 2a - Land Management control alternatives applicable for controlling land uses and activites of interest are listed in Table 6-7. The pollutants which are significantly affected by the application of these control alternatives to the land uses and activities listed are also presented in the table. Further explanation of the nature, effectiveness, etc., of the various techniques is presented in Appendix G, along with performance and cost information.

Step 2d (Item 3) - In this step, the actual pollutant reductions which can be expected by application of Land Management control alternatives to the land uses and activities of concern are calculated. Based on the load-reduction requirements recorded in Item 2, the user can identify a land use activity for potential control. Based on the amount of reduction achieved by the various Land Management control alternatives applied, if one alternative does not produce the required reduction for any particular parameter, various combinations of alternatives can be considered. A combination which achieves the required reductions for all parameters specified in the load-reduction strategy should be selected. If more than one alternative or combination of alternatives could be used to control a particular parameter or parameters, both should be carried forward to the cost-determination steps in order to choose the control alternative that would be most effective on the basis of monetary cost.

TABLE 6-7
LISTING OF LAND MANAGEMENT CONTROL ALTERNATIVES
APPLICABLE TO DIFFERENT LAND USES AND LAND USE ACTIVITIES[1]

Land Use or Land Use Activity	Applicable Land Management Control Alternatives	Principal Pollutants Affected				
		BOD_5	N	P	TSS	TC
High Density Residential	Street Sweeping	X			X	
Medium Density Residential	Street Sweeping	X			X	
	Sediment and Erosion Control	X	X	X	X	
	Septic Tank Management	X	X	X		X
Low Density Residential	Sediment and Erosion Control	X	X	X	X	
	Septic Tank Management	X	X			X
Other Developed Areas	Sediment and Erosion Control	X	X	X	X	
Commercial Areas	Street Sweeping	X			X	
Industrial Sites	Site Runoff Controls	X	X	X	X	
Landfill Sites	Operation Regulations	X	X			
	Design Practices	X	X			X
New Development	Sediment and Erosion Control	X	X		X	
	Zoning/Subdivision Regulation	X	X	X	X	X
	Site Design Restrictions	X	X	X	X	

[1]Limited to consideration of urban non-point sources.

6.4.2.6 Collection System Control Methodology

Discussion

The purpose of investigating collection system control alternatives is to determine whether such controls can reduce the runoff-pollutant load sufficiently to meet the desired water quality objectives. These controls may be employed to reduce the quantity of storm runoff which overflows to a stream during a storm event, or to reduce the pollutant loading of this runoff. Maximizing the use of the existing sewer system for storage of runoff will reduce the volume of overflow which must be stored or treated external to the system during the storm event. Also, this will enable the plant to handle the storm runoff over a longer period of time, and thus reduce the occurrence of overflows. Increasing the conveyance capability of the collection system can reduce the frequency of overflows by making the system better able to handle storm flows. Regular flushing of the sewer system helps to minimize the accumulation of material which settles out of the dry-weather flow and then is subject to scouring and discharge during the higher wet-weather flows.

Existing data show that maximizing in-line storage and conveyance along with the use of selective sewer flushing are effective techniques in reducing pollution attributable to sewer overflows. In addition, their costs are minimal compared to other control alternatives, and they should be seriously considered in situations where control of combined or storm sewer overflows is desirable.

Other collection-system control alternatives are available. In some (e.g., catch-basin cleaning, improved sewer design and maintenance, inflow control), the impact on alleviating overflow pollution is less certain than with the techniques already mentioned. Others (sewer separation, sewer rehabilitation) are partially effective, but are also much more costly. Information concerning these control alternatives, as well as on those already discussed, is included in Appendix G; both cost and performance data are presented where available.

The intent of the COLLECTION SYSTEM CONTROL METHODOLOGY is to guide the user in selecting control alternatives which have the best chance of providing

significant pollution control at a minimum cost. Much of the cost and performation on these alternatives is still being developed and thus cannot be presented in this document. Where this is the case, or where assessment or implementation methodologies are presented in current literature, the highlights of the approach are presented here, and references are made to specific documents for further information.

Methodology Logic

A summary of the logic of the COLLECTION SYSTEM CONTROL METHODOLOGY is presented in Figure 6-16. An expanded flowchart, Figure 6-17, lists the steps to be taken in determining performance and costs. The worksheets for recording the operations are presented as Table 6-8. Notes concerning the methodology steps and worksheet items are presented after the worksheets.

FIGURE 6-16

COLLECTION SYSTEM CONTROL METHODOLOGY
LOGIC SUMMARY

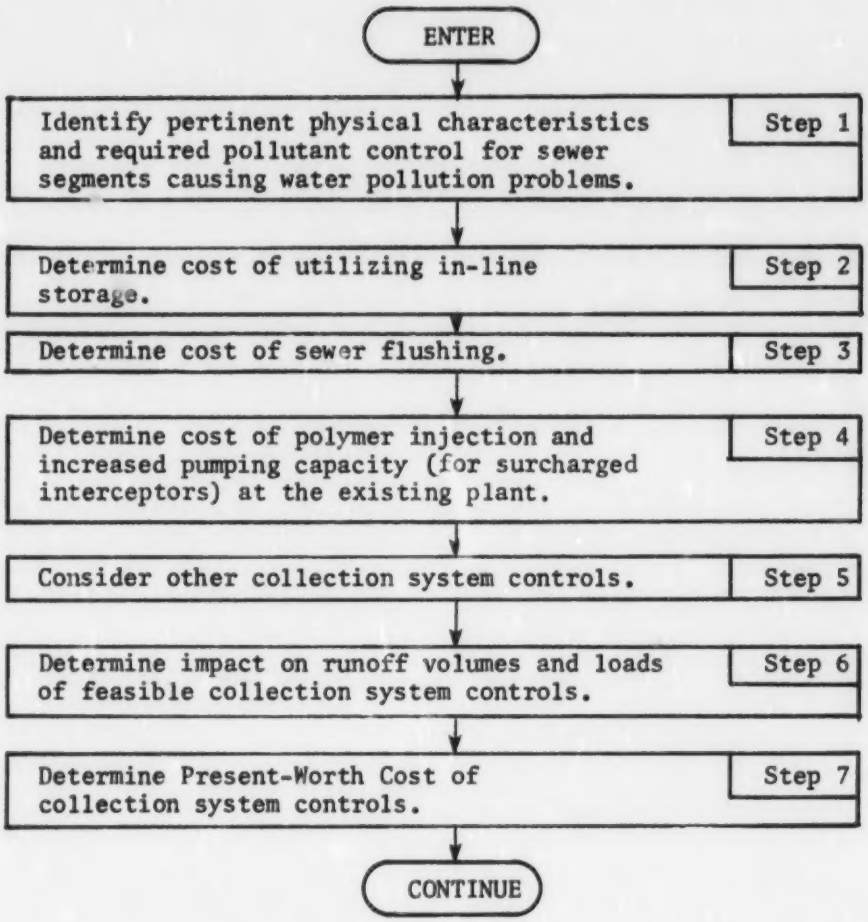
ENTER
Identify pertinent physical characteristics and required pollutant control for sewer segments causing water pollution problems.
Step 1
Determine cost of utilizing in-line storage.
Step 2
Determine cost of sewer flushing.
Step 3
Determine cost of polymer injection and increased pumping capacity (for surcharged interceptors) at the existing plant.
Step 4
Consider other collection system controls.
Step 5
Determine impact on runoff volumes and loads of feasible collection system controls.
Step 6
Determine Present-Worth Cost of collection system controls.
Step 7
CONTINUE

FIGURE 6-17

COLLECTION SYSTEM CONTROL METHODOLOGY
FLOWCHART

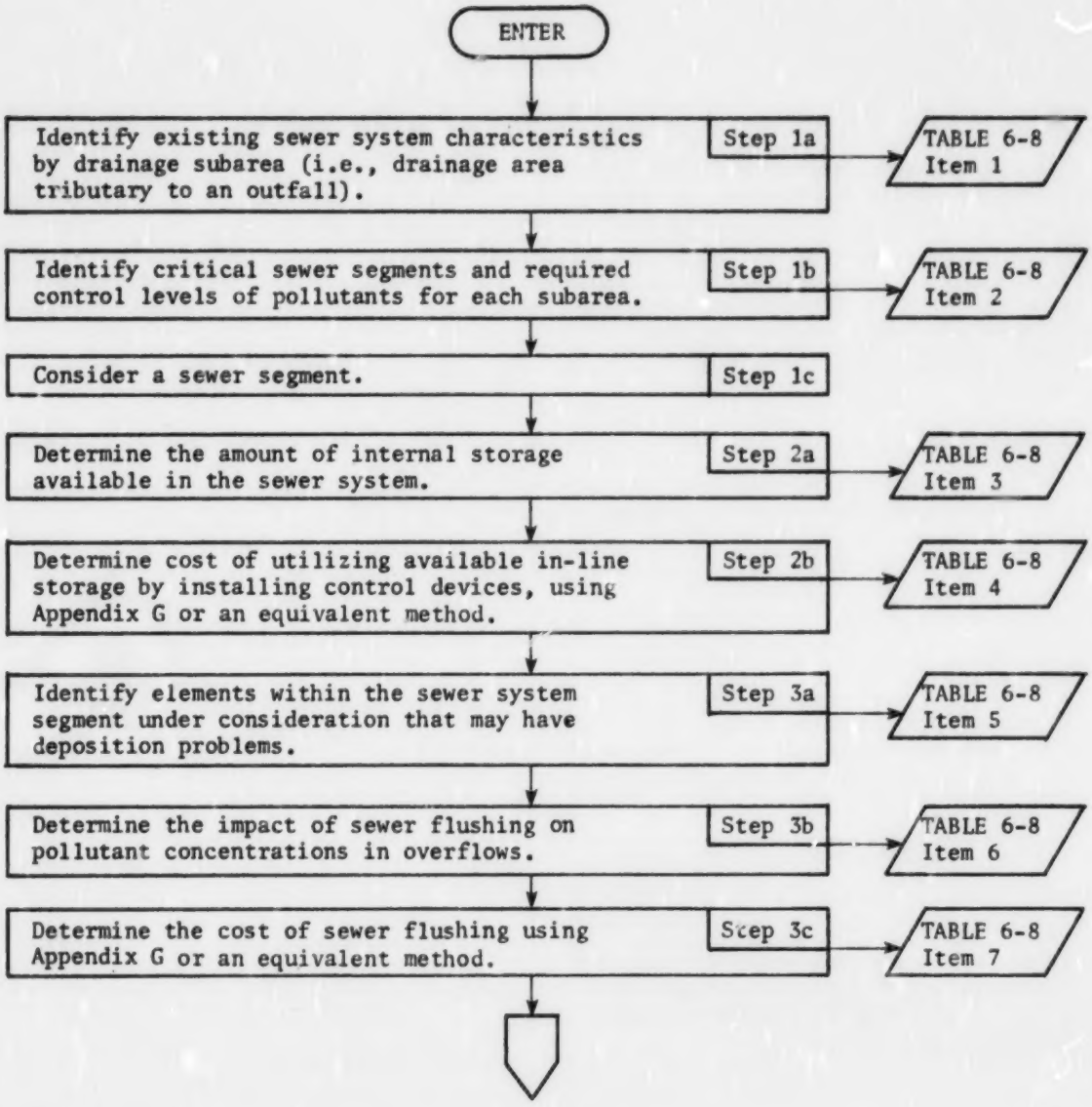
ENTER
Identify existing sewer system characteristics by drainage subarea (i.e., drainage area tributary to an outfall).
Step 1a
TABLE 6-8 Item 1
Identify critical sewer segments and required control levels of pollutants for each subarea.
Step 1b
TABLE 6-8 Item 2
Consider a sewer segment.
Step 1c
Determine the amount of internal storage available in the sewer system.
Step 2a
TABLE 6-8 Item 3
Determine cost of utilizing available in-line storage by installing control devices, using Appendix G or an equivalent method.
Step 2b
TABLE 6-8 Item 4
Identify elements within the sewer system segment under consideration that may have deposition problems.
Step 3a
TABLE 6-8 Item 5
Determine the impact of sewer flushing on pollutant concentrations in overflows.
Step 3b
TABLE 6-8 Item 6
Determine the cost of sewer flushing using Appendix G or an equivalent method.
Step 3c
TABLE 6-8 Item 7

FIGURE 6-17 (CONTINUED)

COLLECTION SYSTEM CONTROL METHODOLOGY
FLOWCHART

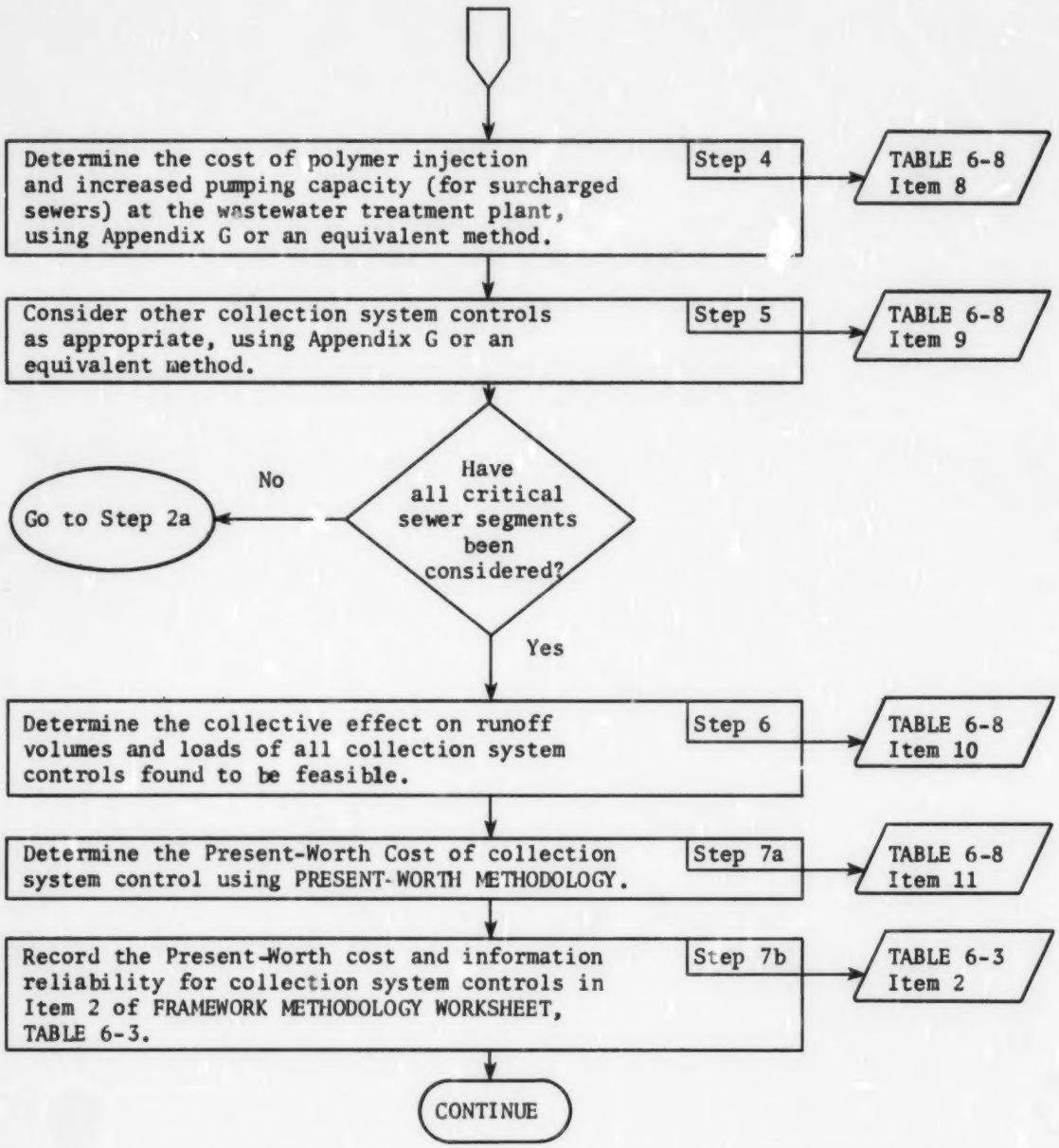
Determine the cost of polymer injection and increased pumping capacity (for surcharged sewers) at the wastewater treatment plant, using Appendix G or an equivalent method.
Step 4
TABLE 6-8 Item 8
Consider other collection system controls as appropriate, using Appendix G or an equivalent method.
Step 5
TABLE 6-8 Item 9
Have all critical sewer segments been considered?
No
Go to Step 2a
Yes
Determine the collective effect on runoff volumes and loads of all collection system controls found to be feasible.
Step 6
TABLE 6-8 Item 10
Determine the Present-Worth Cost of collection system control using PRESENT-WORTH METHODOLOGY.
Step 7a
TABLE 6-8 Item 11
Record the Present-Worth cost and information reliability for collection system controls in Item 2 of FRAMEWORK METHODOLOGY WORKSHEET, TABLE 6-3.
Step 7b
TABLE 6-3 Item 2
CONTINUE

TABLE 6-8
COLLECTION SYSTEM CONTROL METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgments presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach available (or even as the preferred approach). However, any approaches used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other EPA, State and local guidelines and regulations.

Item 1 Sewer System Characteristics.

Outfall No.	Subarea Location[1]	Sewer Segment Type[2]	Type of Overflow Control Device[3]
1			
2			
3			
4			
5			

[1]Locations should be referenced to a map using outfall and subarea numbers.

[2]Combined sewer, storm sewer or unsewered.

[3]Swirl separator or conventional regulator.

By _____ Date _____ Strategy No. _____
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Remarks. _____ Page _____

TABLE 6-8 (continued)
COLLECTION SYSTEM CONTROL METHODOLOGY
WORKSHEET

Item 2 Pollutants (BOD_5, TSS, TC, P, N) to be controlled (from Load Reduction Strategy Matrix developed in Chapter 5.

Segment No.	Pollutant Parameter	Required % Reduction

Item 3 In-line storage volume.

Segment No.	Hydraulic Capacity	Dry Weather Flow	Internal Storage Capacity

By _____ Date _____ Strategy No. _____
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Remarks: _____ Page _____

TABLE 6-8 (continued)
COLLECTION SYSTEM CONTROL METHODOLOGY
WORKSHEET

Item 4 Cost of utilizing available in-line storage from cost information information in Appendix G, or an equivalent method.

Segment No.	Type of Control[1]	Construction Costs	O&M Cost	Total Present Worth Costs[2]

Item 5 Sewer segments with deposition problems.

Segment No.	Extent of Problem	Source of Problem[3]

[1] Weir, gate, etc.

[2] Using PRESENT-WORTH METHODOLOGY

[3] Obstructions, slack velocity, etc.

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TABLE 6-8 (continued)
COLLECTION SYSTEM CONTROL METHODOLOGY
WORKSHEET

Item 6 Impact of sewer flushing on pollutant concentrations in overflows.

Outfall No.	Segment No.	Pollutant Parameter	Concentration Before	Concentration After

Item 7 Cost of sewer flushing using cost information in Appendix G, or an equivalent method.

Segment No.	O&M	Total Present-Worth Costs

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Remarks: _____ Page _____

TABLE 6-8 (continued)
COLLECTION SYSTEM CONTROL METHODOLOGY
WORKSHEET

Item 8 Cost of measuring conveyance capability using cost curves in Appendix G or an equivalent method.

i. Polymer injection costs.

Segment No.	Construction Costs	O&M Costs	Total Present-Worth Costs[1]

ii. Increased pumping capacity at the wastewater treatment plant where influent interceptor is surcharged.

Existing Capacity	Increased Capacity	Construction Cost	O&M Costs	Total Present-Worth Costs[1]

[1]Using PRESENT-WORTH METHODOLOGY

By _____ Date _____ Strategy No. _____
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Remarks: _____ Page _____

TABLE 6-3 (continued)
COLLECTION SYSTEM CONTROL METHODOLOGY
WORKSHEET

Item 9 Cost of other collection system controls as appropriate, using Appendix G or an equivalent method.

Segment No.	Type of Control	Construction Costs	O&M Costs	Total Present-Worth Costs[1]

[1]Using PRESENT-WORTH METHODOLOGY

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks. _____ Page _____

TABLE 6-8 (continued)
COLLECTION SYSTEM CONTROL METHODOLOGY
WORKSHEET

Item 10 Collective effect on runoff volumes and loads of all collection system controls found to be feasible.

Segment No.	Control Alternative	% Runoff Controlled	Pollutant Parameter	Load Reduction Achieved

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Remarks. _____ Page _____

TABLE 6-8 (continued)
COLLECTION SYSTEM CONTROL METHODOLOGY
WORKSHEET

Item 11 Summary of feasible collection system control alternatives.

Collection System Control	Present-Worth Costs

Total _____

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

Notes on Methodology Logic

Step 1a (Item 1) - Pertinent sewer-system and drainage subarea characteristics are discussed in Section 3.4.4 (Chapter 3), including presentation of a simulation technique for the assessment of storm loads and the effect of control measures. The technique described in Section 3.4.4 is a summary of a methodology presented in reference (2). The user is referred to this reference for more information on this simulation technique.

Step 1b (Item 2) - Pollutants to be controlled and the degree of reduction required are specified in the Load-Reduction Strategy Matrix developed in Chapter 6.

Step 2a (Item 3) - It is often possible to use the available internal storage capacity of sewer systems more effectively by installing flow-regulation devices to retain storm runoff or by routing runoff flows through the sewer system so as to maximize detention time. The first step in attempting to reduce the overflows by using these methods is to determine the hydraulic capacities of existing sewer interceptors and the magnitude of the dry-weather flow. The difference between these two values is an indication of the capacity in the interceptor which might be available for internal storage. The planner can use this information, along with information on slopes of the sewer lines, to determine where the control devices could be placed to best utilize the existing storage capacity. Detailed application of this alternative depends on the specific area being examined and, thus, this methodology must remain in general terms. Users are referred to references (2), (3), (4), (5), (6), (7).

Step 2b (Item 4) - In most cases, the cost of in-line storage will be the cost of installing regulator devices within the sewer system to utilize existing available capacity. For sophisticated systems, costs will also include remote-control instrumentation and automation.

Step 3a (Item 5) - Certain parts of a sewer system may be subject to the settling of the solids contained in the dry-weather flow. In most cases, this is because the slope is insufficient to maintain a velocity which will keep the solids in suspension. These are candidates for a sewer-flushing program which will remove the deposited material during dry-weather periods.

This will help prevent later scouring of these solids, which adds to the pollutant loading of the first flush during a storm.

Step 4 (Item 8) - The conveyance capability of a sewer system can be improved by several methods, including polymer injection and increasing pumping capacity of the influent pump station where the interceptor to the plant is surcharged. Polymer injection during storms into sewer segments subject to surcharging can reduce hydraulic friction thus increasing carrying capacity and possibly eliminating the surcharge condition. Also, increased pumping rates at the head of a treatment plant in anticipation of a storm event will create more capacity within the sewer system for conveyance and storage of storm flows.

6.4.2.7 Storage/Treatment Methodology

Discussion

The storage and treatment of combined and storm sewer overflows has received much attention in recent years. New approaches and new technologies are being developed on a continuing basis. The feasibility, cost, and performance of storage/treatment alternatives are in some cases unproven or uncertain, and usually are highly dependent on site-specific factors, such as location of overflow points in relation to existing interceptors and treatment facilities, available capacity of wastewater treatment units and sludge handling facilities, and rainfall and runoff characteristics.

The following methodology is presented: to aid the user in recognizing the aspects of the problem that must be addressed; to provide available information in some of the key factors to be considered; and to suggest alternative approaches for handling sewer overflow problems by using storage and treatment. Again, the user should keep in mind that the alternatives suggested are not necessarily the only ones that might prove effective.

Storage/treatment control alternatives are the last resort in controlling storm overflows. Because they usually involve the construction of facilities, their cost is higher than the other wet-weather control alternatives. However, it is often necessary to resort to them, especially in large basins, because it is difficult to control the large volumes of water and high pollutant loads using land management or collection system controls alone.

For an understanding of the state-of-the-art in urban runoff pollution control technology and programs currently underway, the user should consult pertinent EPA documents on urban runoff and urban stormwater management, including references (8) and (9).

Methodology Logic

A summary of the methodology logic is presented in Figure 6-18. An expanded flowchart, Figure 6-19, lists the steps to be taken in determining performance and costs. The worksheets for recording the operations are presented as Table 6-9. Notes concerning the methodology steps and work sheet items are presented after the worksheets.

730<

FIGURE 6-18

STORAGE/TREATMENT METHODOLOGY
LOGIC SUMMARY

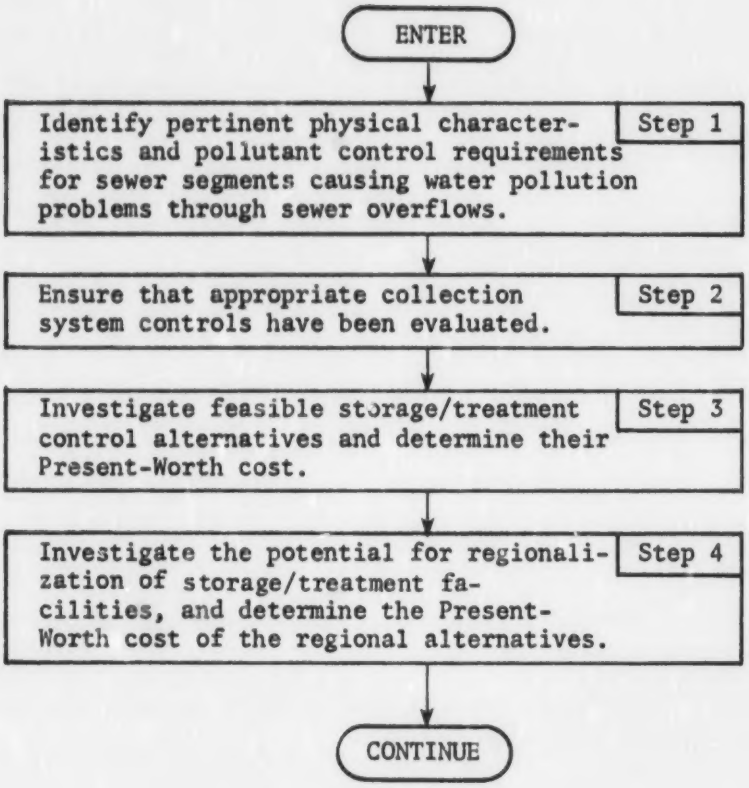

ENTER
Identify pertinent physical characteristics and pollutant control requirements for sewer segments causing water pollution problems through sewer overflows.
Step 1
Ensure that appropriate collection system controls have been evaluated.
Step 2
Investigate feasible storage/treatment control alternatives and determine their Present-Worth cost.
Step 3
Investigate the potential for regionalization of storage/treatment facilities, and determine the Present-Worth cost of the regional alternatives.
Step 4
CONTINUE

FIGURE 6-19

STORAGE/TREATMENT METHODOLOGY
FLOWCHART

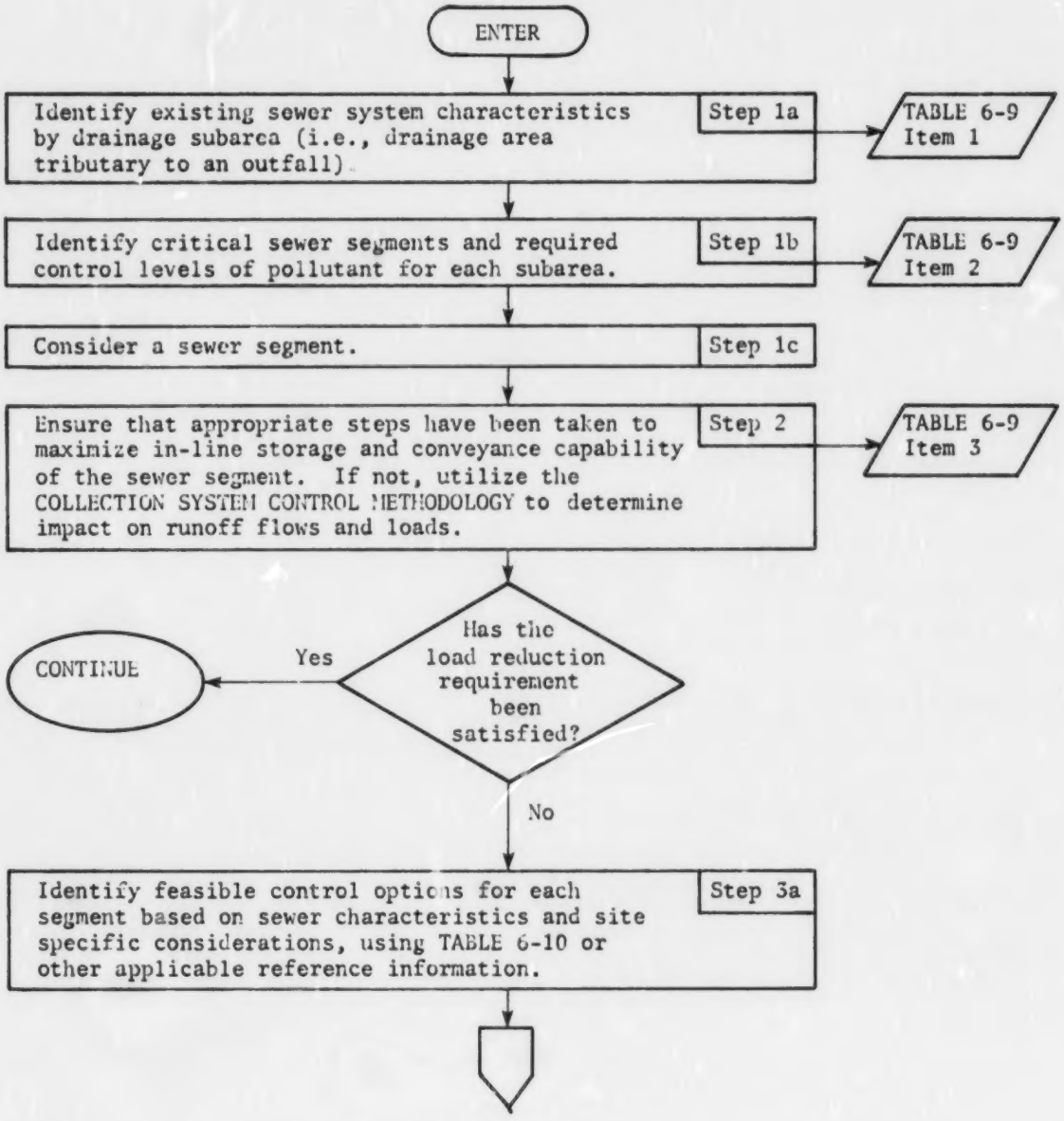

ENTER
Identify existing sewer system characteristics by drainage subarea (i.e., drainage area tributary to an outfall)
Step 1a
TABLE 6-9 Item 1
Identify critical sewer segments and required control levels of pollutant for each subarea.
Step 1b
TABLE 6-9 Item 2
Consider a sewer segment.
Step 1c
Ensure that appropriate steps have been taken to maximize in-line storage and conveyance capability of the sewer segment. If not, utilize the COLLECTION SYSTEM CONTROL METHODOLOGY to determine impact on runoff flows and loads.
Step 2
TABLE 6-9 Item 3
Has the load reduction requirement been satisfied?
Yes
CONTINUE
No
Identify feasible control options for each segment based on sewer characteristics and site specific considerations, using TABLE 6-10 or other applicable reference information.
Step 3a

FIGURE 6-19 (CONTINUED)

STORAGE/TREATMENT METHODOLOGY
FLOWCHART

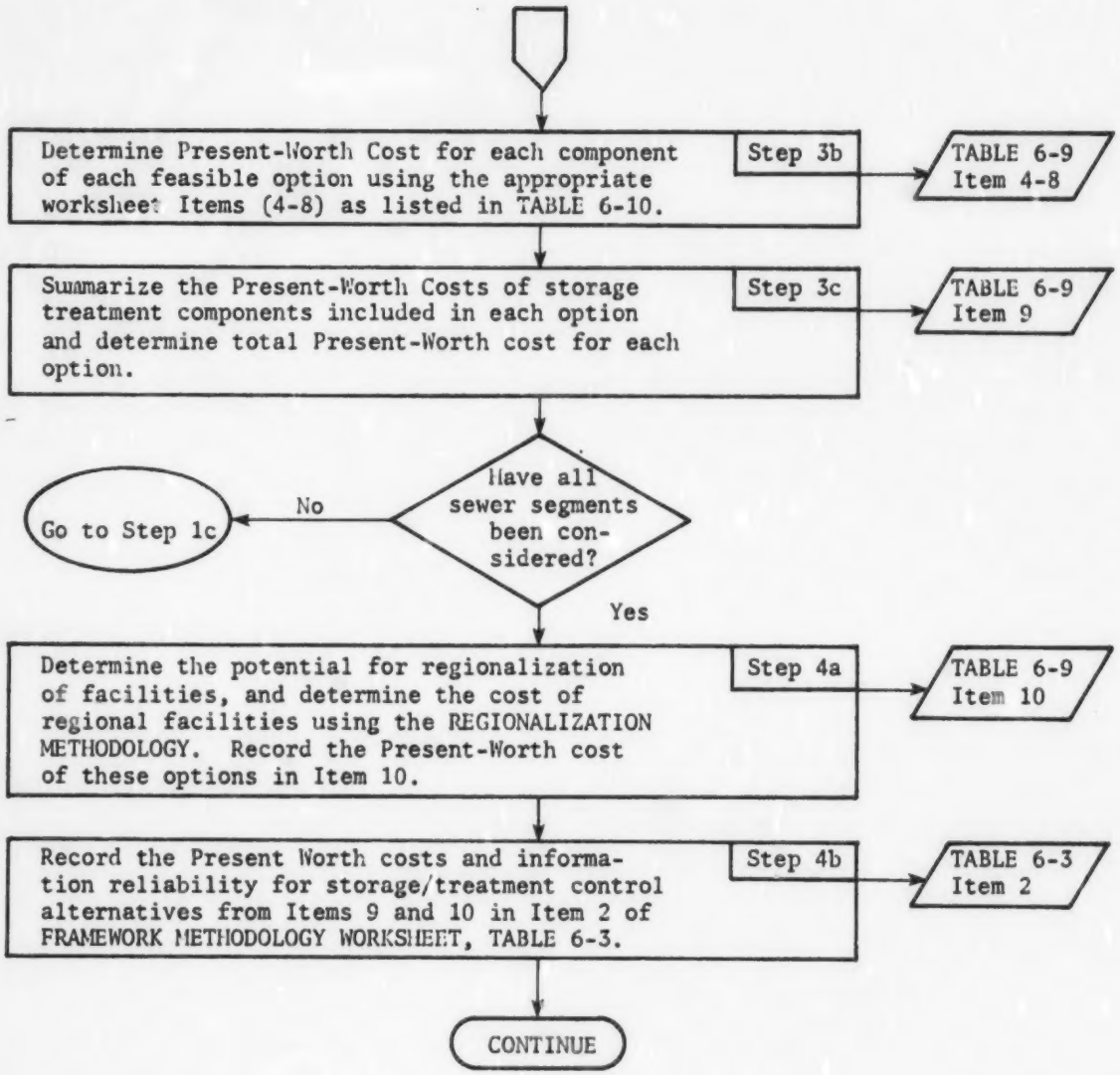

Determine Present-Worth Cost for each component of each feasible option using the appropriate worksheet Items (4-8) as listed in TABLE 6-10.
Step 3b
TABLE 6-9 Item 4-8
Summarize the Present-Worth Costs of storage treatment components included in each option and determine total Present-Worth cost for each option.
Step 3c
TABLE 6-9 Item 9
Have all sewer segments been considered?
No
Go to Step 1c
Yes
Determine the potential for regionalization of facilities, and determine the cost of regional facilities using the REGIONALIZATION METHODOLOGY. Record the Present-Worth cost of these options in Item 10.
Step 4a
TABLE 6-9 Item 10
Record the Present Worth costs and information reliability for storage/treatment control alternatives from Items 9 and 10 in Item 2 of FRAMEWORK METHODOLOGY WORKSHEET, TABLE 6-3.
Step 4b
TABLE 6-3 Item 2
CONTINUE

TABLE 6-9
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgments presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach available (or even as the preferred approach). However, any approaches used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other EPA, State, and local guidelines and regulations.

Item 1 Sewer System Characteristics.

Outfall No.	Subarea Location[1]	Sewer Segment Type[2]	Type of Control Device[3]

[1]Locations should be referenced to a map using Outfall and Subarea numbers.
[2]Combined sewer, storm sewer, or unsewered.
[3]Swirl separator or conventional regulator.

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 2 Pollutant Parameters (BOD_5, TSS, TC, P, N).

Segment No.	Pollutant Parameter	Required % Reduction

Item 3 Results of collection system controls.

i. Quantity of design storm runoff volume stored in internal storage of collection system _____ mg.

ii. Remaining runoff volumes and load:
Volume: _____ mg.
Flow: _____ mgd.
Load: _____ mg/l BOD_5
_____ mg/l TSS
_____ mg/l P
_____ mg/l N
_____ #/100 ml

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 4 i. Cost of Regulator, from information in Appendix G, or equivalent method.

Construction Cost $ _____

O&M Cost $ _____

Total Present-Worth Cost $ _____
(using PRESENT-WORTH METHODOLOGY)

ii. Cost of swirl separator, using Table 6-11, or equivalent method.

Design flow _____

Construction Cost $ _____

O&M Cost $ _____

Total Present-Worth Cost $ _____
(using PRESENT-WORTH METHODOLOGY)

Item 5 Cost of storage tanks, from Table 6-11, or equivalent method.

Type of storage: Settling _____ Complete mix _____

Construction Cost $ _____

O&M Cost $ _____

Total Present-Worth Cost $ _____
(using PRESENT-WORTH METHODOLOGY)

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 6

i. Design Storm Characteristics.

Intensity _____ in/hour

Duration _____ hour

Frequency _____ /year

ii. Inlet hydrograph(s) for design storm (storm runoff entering the sewer system).
Method _____

Sub-area ___		Sub-area ___		Sub-area ___	
TIME	FLOW	TIME	FLOW	TIME	FLOW

NOTE: Plot hydrographs for each subarea on separate sheets of graph paper.

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 6 - Continued

iii. Inflow hydrograph to overflow control structure.

Routing Procedure _____

TIME	FLOW

iv. Overflow hydrograph from the control structure.

(Attach rating curve for specific structure)

TIME	FLOW

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 6 - Continued

v. Mass Curve from Overflow hydrograph.

TIME	INCREMENTAL VOLUME	CUMULATIVE VOLUME

NOTE: Plot Mass Curve on separate sheet of standard graph paper.

vi. Storage/Treatment requirements.

% MAXIMUM TREATMENT RATE	TREATMENT RATE	STORAGE VOLUME
100	_____	0
75	_____	_____
50	_____	_____
25	_____	_____
0	0	_____

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

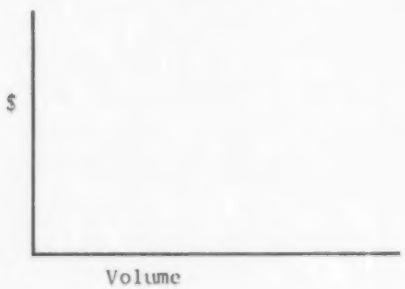
TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 6 - Continued

vii. Cost of storage, using cost functions from Table 6-11, or equivalent method, PRESENT-WORTH METHODOLOGY.
Type of storage _____.

Volume to be Stored	Construction Cost	O&M Cost	Present Worth Cost

NOTE: Plot Volume to be stored and Present Worth Cost.



By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 6 - Continued

viii. Cost of on-site treatment, using cost functions from Table 6-11, or equivalent method, and PRESENT-WORTH METHODOLOGY.

Treatment Unit _____

Treatment Rate	Construction Cost	O&M Cost	Present-Worth Cost

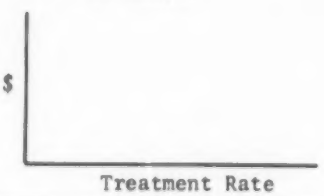
Treatment Unit _____

Treatment Rate	Construction Cost	O&M Cost	Present-Worth Cost

Treatment Unit _____

Treatment Rate	Construction Cost	O&M Cost	Present-Worth Cost

NOTE: Plot a cost curve for each type of treatment unit on the same set of axes.



By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 6 - Continued

ix. Cost of treatment at the existing plant.

a) Cost of discharging effluent to the interceptor and treating at existing plant.

i. If interceptor is adjacent to overflow control device (as in combined sewer), no cost is associated with discharge to the interceptor.

ii. If interceptor is not adjacent to the overflow control device, the cost to construct a sewer to transport the effluent can be determined using the TRANSPORTATION COST METHODOLOGY and PRESENT-WORTH METHODOLOGY.

Flow to be Transported and Treated	Sewer Construction		Present-Worth Cost
	Construction Cost	O&M Cost	

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 6 - Continued

b) Costs of upgrading/expanding existing treatment facility using TREATMENT FACILITY METHODOLOGY and PRESENT-WORTH METHODOLOGY.

Treatment Rate	Construction Cost	O&M Cost	Present-Worth Cost

c) Total Present-Worth cost of treatment at existing facility.

Treatment Rate	Total Present-Worth Cost of Transportation and Treatment

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 6 - Continued

x. Least-cost combination of storage and treatment.

Treatment Rate	Least-cost Treatment Unit	Present-Worth Cost of Treatment	Storage Volume	Present-Worth Cost of Storage	Total Present-Worth Cost

NOTE: Plot toal Present-Worth cost of storage and treatment versus treatment rate.

Least-cost combination of storage and treatment.

$ _____

By _____ Date _____ Strategy No. _____
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Remarks: _____ Page _____

TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 7

i. Cost of laying pipe to connect new regulator to existing outfall pipe (if significant), or cost of laying a new or larger outfall pipe, from cost curve in Appendix H, Figure H-84.

Construction Cost $ _____

O&M Cost $ _____

Total Present-Worth Cost $ _____
(using PRESENT-WORTH METHODOLOGY)

ii. Cost of Disinfection (where required) from curve in Appendix H, Figure H-26.

Construction Cost $ _____

O&M Cost $ _____

Total Present-Worth Cost $ _____
(using PRESENT-WORTH METHODOLOGY)

By _____ Date _____ Strategy No. _____
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Remarks: _____ Page _____

TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 8 Cost of sludge handling.

i. On-site sludge handling.
   a. Sludge treatment (using cost curves in Appendix H).
      1) Organic sludges

         Lime stabilization (Figure H-79)
           Construction Cost $ _____
           O&M Cost $ _____

         Vacuum Filtration (Figure H-68)
           Construction Cost $ _____
           O&M Cost $ _____

      2) Inorganic sludges

         Vacuum Filtration (Figure H-69)
           Construction Cost $ _____
           O&M Cost $ _____

      3) Subtotal $ _____

   b. Sludge transport (using cost curves in Appendix H, Figures H-86 through H-90).

      Method: _____
           Construction Cost $ _____
           O&M Cost $ _____

   c. Sludge disposal (using cost curves in Appendix H, Figures H-81 through H-83).

      Method: _____
           Construction Cost $ _____
           O&M Cost $ _____

   d. Total cost for on-site sludge handling.

           Construction Cost $ _____
           O&M Cost $ _____

   e. Total Present-Worth Cost $ _____
      (using PRESENT-WORTH METHODOLOGY)

ii. Sludge handling at existing wastewater treatment facility.
   a. Sludge transport to existing facility

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 8 - Continued

1) If sewer is storm sewer, determine cost to construct sewer to connect with sanitary sewer interceptor to treatment plant, using TRANSPORTATION COST METHODOLOGY.

Construction Cost $ _____
O&M Cost $ _____

2) If sewer is combined, existing interceptor capacity should be sufficient to transport sludges to the existing wastewater treatment plant.

b. Sludge treatment.

Determine if there is capacity available in existing sludge handling facilities to accept additional sludge volumes from the treatment of storm overflows. If not, determine cost to provide additional sludge handling capacity at the existing facility, using TREATMENT FACILITY METHODOLOGY.

Construction Cost $ _____
O&M Cost $ _____

c. Sludge disposal (using cost curves in Appendix H, Figures H-81, 82, or 83).

Method: _____
Construction Cost $ _____
O&M Cost $ _____

d. Total cost for sludge handling at existing wastewater treatment facilities.

Construction Cost $ _____
O&M Cost $ _____

e. Total Present-Worth Cost $ _____
(using PRESENT-WORTH METHODOLOGY)

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 9 Total Present Worth Cost.

Sewer Segment _____ Sewer Type _____

i. For each storage/treatment option, record the Present-Worth costs of each component determined using Items 4-8.

ii. Determine the total Present-Worth cost of each option.

Present-Worth Cost (in $1,000)

Option #	Regulator	Swirl	Storage w/ Settling	Storage w/ mixing	On-site WW Treatment	Treatment at Existing Plant	Interceptor Construction	Disinfection	On-site Sludge Handling	Sludge Handling at Existing Plant	Total Present Worth Cost

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 10 Regionalization of storage/treatment components, using REGIONALIZATION METHODOLOGY.

Components regionalized:

Regional Facility:

Construction Cost $ _____

O&M Cost $ _____

Present-Worth Cost $ _____
(using PRESENT-WORTH METHODOLOGY)

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

Notes of Methodology Logic

Step 1a (Item 1) - Pertinent sewer system and drainage area characteristics are discussed in Section 3.4.4 (Chapter 3), along with the presentation of a simulation technique for the assessment of storm loads and of the effect of control measures. The technique described in Section 3.4.4 is a summary of a methodology presented in the EPA document on Development and Application of a Simplified Stormwater Management Model (EPA-600/2-76-218). The user should consult this reference for more information on this simulation technique.

Step 1b (Item 2) - Pollutants to be controlled and the percentage reductions required are specified in the Load-Reduction Strategy Matrix (illustrated for the South River hypothetical example in Table 6-19).

Step 2a (Item 3) - The maximizing of storage and conveyance capability, as well as other collection system controls such as sewer flushing, was described in the COLLECTION SYSTEM CONTROL METHODOLOGY. It is mentioned again here to emphasize the importance of this alternative in controlling wet-weather flows. These alternatives are so effective in reducing sewer overflows, and have such relatively minor cost, that any consideration of storing and treating sewer overflows should be considered in conjunction with these collection-system controls. This step insures that the user has considered these alternatives, and is using a load which has been modified to take into account the effect of the collection system. If the total load-reduction requirement specified in the Load-Reduction Strategy Matrix has been achieved using the collection system controls, the user need go no further. If not, the user should continue with the STORAGE/TREATMENT METHODOLOGY and consider various storage/treatment control alternatives.

Step 3a - The identification of feasible control options for storage and/or treatment of sewer overflows should be based on the specific situation under investigation. Choices must be made concerning: the type of regulator to be used; the type and capacity of the storage device; the type, degree, and location of treatment required; the type, capacity, and location of sludge-handling facilities; and numerous other factors. The following paragraphs are provided to aid the user in addressing some of these decisions. This discussion should be viewed as a guide only, and is not intended to be

prescriptive in any way. Table 6-10 presents feasible combinations of the storage/treatment components already mentioned, and lists the worksheet item number which can be used to obtain a Present-Worth cost of the components based on the flow and load information from Steps 1 and 2. The user should consult the following discussion and other applicable references to aid in determining which control option is applicable to his situation.

Flow Regulation - In determining the type of flow regulation to provide at a sewer overflow location, it will be necessary first to determine the types of regulators already in the system. Of course, storm sewers will not have regulators, because the total flow in a storm sewer is discharged to the receiving water. Combined sewers, in most cases, will have a conventional type of regulator device of varying degrees of sophistication, ranging from a simple weir to a dynamic device which has moving parts and can be controlled from remote locations. However, a significant number of unattended regulators regularly malfunction because parts are frozen in an undesirable position, or pieces are broken off, often allowing a continual dumping of dry-weather flow to the receiving water. Thus, it is probable that a new regulator device or repair of existing regulators will be necessary in many cases.

The user may consider installing either a conventional regulator (which will provide flow regulation alone) or a swirl regulator/separator device (which will provide flow regulation plus solids removal). The swirl device can be designed to provide solids separation up to a certain design flow and then to bypass additional flows.

As far as the subsequent storage or treatment components are concerned, the basic difference between the swirl separator and the conventional regulator is that the swirl separator provides both an effluent flow (light fraction) and a more concentrated underflow, one or both of which may be handled by the storage/treatment components. The conventional regulator merely bypasses those flows which are in excess of the hydraulic capacity of the existing interceptor and/or wastewater treatment plant.

Storage - Off-line storage of the sewer overflow in the vicinity of the overflow location can be either of two basic types: storage with settling,

TABLE 6-10
WETWEATHER FLOW STORAGE/TREATMENT CONTROL OPTIONS

Sewer Type	Storage/Treatment Components	Worksheet Item No.	Control Options 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Combined Sewer	1	X	X	X	X	X	X	X	X	X	X	X														
	Storm Sewer	1												X	X	X	X	X	X	X	X	X	X	X	X	X	X
Regulation	Conventional Regulator	4								X	X	X	X	X										X	X	X	X
	Swirl Separator	4	X	X	X	X	X	X	X							X	X	X	X	X	X	X	X				
Storage	Storage with Settling	5		Es	Es				Or	Or						Ss				Es	Es		Or	Or			
	Storage with Complete Mix	5			Es	Es	Es				Or	Or	Or				Ss	Es	Es			Es	Es		Or	Or	Or
Wastewater Treatment	On-Site High Rate Treatment	6				Em	Em				Em	Em					Em	Em	Et	Et						Em	Em
	Interceptor to Existing Plant And Treatment	6				Em					Em				Et*	Em*					Em*	Em*			Em*		
Overflow	Disinfection**/ Outfall	7	Es	Et	Et		Ed	Ed	Et	Et		Ed	Ed	Es	Es	Es	Ed	Ed	Ed	Ed				Et	Et		Ed	Ed
Sludge Handling	On-Site Treatment	8			St			Sd		St			Sd		St		Ss, Sd		Ss, Sd			Ss		St		Sd
	Interceptor to Existing Plant and Treatment	1	Ss, Ss	St	Ss	Ss, Sd	Ss	St		Sd		Ss*						Ss*, Sd*			Ss*, Sd*	Ss*		St*		Sd*	

Or = Regulator Overflow
Es = Swirl Separator Light Fraction
Et = Effluent from Settling Tank
Em = Effluent from Mix Tank
Ed = Effluent from Hi-Rate TMT Device
Ss = Underflow from Swirl Separator
St = Settled Sludge
Sd = Sludge from High-Rate Treatment
* May involve transportation of effluent or sludge if storm overflow location is not near a sanitary sewer interceptor.
** Disinfection is optional based on site specific requirements.

and storage with complete mix. Any storage of storm overflows without specific provisions to keep the solids suspended will result in some settling of the solids in the storage basin. The basin can be designed to remove the solids and thus act as a primary settling tank. Alternatively, the solids may be allowed to settle and other means of removing the solids may be employed, such as washing down the basin after the effluent is pumped out. Depending on the load-reduction requirements, storage with settling may provide treatment sufficient to allow the effluent from the settling tank to be discharged directly to the receiving water, with disinfection as the only other treatment required. If not, the effluent must receive additional treatment.

Storage with complete mix is usually accomplished through mechanical mixers or aerators. In most cases, the effluent from the complete-mix tank will require additional treatment before discharge to the receiving water. Occasionally the storage tank will need washing down after emptying to avoid odor and solids-accumulation problems. This will depend in part on the effectiveness of the mixers.

These two techniques can be used in conjunction. For example, a facility in Milwaukee, Wisconsin was designed to allow settling during the storm event, since there was a reasonable chance that the total storm runoff volume entering the tank would exceed the tank's volumetric capacity. By allowing settling during the storm flow condition, excessive flow that might overflow the storage tank at least receives primary treatment by sedimentation. After the storm, mechanical mixers are used within the tank to resuspend settled solids as the tank contents are pumped out.

A benefit of having off-line storage facilities for wet-weather flows is that these facilities may also be used for equalization of dry-weather flows. Storage volumes provided for wet-weather flows will probably be more than adequate, since only approximately 20 percent of the average dry-weather flow is needed to provide equalization. The tank could be compartmentalized to handle the smaller dry-weather storage in order to prevent solids from this flow from spreading out over the whole tank.

Wastewater Treatment - Effluents from storage tanks may receive further treatment in facilities provided at the overflow site, or may be transported

through an interceptor to the existing wastewater treatment plant. The location of treatment is selected by determining the least-cost mix of transport and treatment. The tradeoff is between the size of the treatment units plus cost of transportation, if necessary, and the size of the storage device. A treatment unit could be provided at the overflow site or at an existing plant that would treat the full flow expected during the storm event. A smaller unit could be utilized if storage were also made available. Similarly, the provision of storage capacity on-site might make the available capacity at the existing plant sufficient to handle the storm flows. A simplified approach to the storage/treatment optimization is provided in worksheet Item 6. The user can utilize this approach in the preliminary stages of planning, but more detailed evaluation should be made as key decision points are reached.

In determining the optimum mix of storage and treatment from a cost standpoint, cost functions for both storage and treatment must be utilized. Storage may be provided in the sewer lines themselves, or in a tank external to the sewer system. Treatment may be provided at the overflow site by utilizing a high-rate treatment unit, or at the existing treatment plant by utilizing existing facilities or by expanding those facilities. The most attractive combination of these options must be determined for each specific situation. The cost of these options will depend on the degree of treatment required, the excess capacity at the existing wastewater plant, the availability of land at the overflow site for the construction of treatment facilities, the availability of land at the existing wastewater treatment plant site for expanding existing facilities, the sludge handling ability at both sites, the opportunity to build an overflow treatment facility which would serve more than one outfall, and, in the case of the storm sewer, the length of the connecting interceptor which must be constructed to transport storm flows to the sanitary sewer interceptor leading to the existing plant.

As shown in Table 6-11, the swirl separator provides a degree of primary treatment. The settling efficiency of a subsequent storage tank therefore will be less for the swirl light fraction than for the overflow from a conventional regulator because of the partial treatment already provided. Other

TABLE 6-11

SUMMARY OF CONCENTRATION REDUCING TREATMENT
ALTERNATIVES FOR ON-SITE OVERFLOW TREATMENT DEVICES[1,2]

TREATMENT	Typical Pollutant Removals[3] (%)					Hydraulic Loading Rate (gpm/ft^2)	Detention Time (min)	Cost Functions: Amortized Capital (CA)[5] CA=1T^m or CA=1S^m		O & M OM=μT^q		(Annual Cost: $/yr)[4] TOTAL COST (TC) TC=sT^z or TC=sS^z	
	BOD_5	TSS	N	P	FC	Range	Range	1	m	p	q	s	z
1. Microscreens	40-60	70				20		7,343.8	0.76	1,836.0	0.76	9,179.8	0.76
2. Screening/Dissolved Air Flotation	50-60	80				2.5		8,161.4	0.84	2,036.7	0.84	10,198.1	0.84
3. Swirl Separator	25-60	50				60		1,971.0	0.70	584.0	0.70	2,555.0	0.70
4. High-Rate Filtration	60-80	90				24							
5. Disinfection					99.9			(See Appendix H, Figure H-26)					
STORAGE													
1. Storage with settling[6] (i.e., sedimentation)	25-40	55				0.5		32,634.7	0.70	8,157.8	0.70	40,792.5	0.70
2. Storage (high density areas, 15 persons per acre)												51,000.0	1.00
3. Storage (low density areas, 5 persons per acre)												10,200.0	1.00

Notes:
[1] T = Wet-Weather Treatment Rate in mgd; S = Storage Volume in mg.
[2] 100 mgd. No economies of scale beyond 100 mgd.
[3] Reference (9).
[4] Reference (10).
[5] Amortized at 7% over 20 years.
[6] ENR = 2000. Includes land costs, chlorination, sludge handling, engineering, and contingencies. Additional cost information for wet-weather storage and treatment devices can be found in Appendix H, Figures H-17 through H-27.

high-rate treatment units which may be considered for on-site treatment include those listed in Table 6-11, which gives ranges of treatment for various pollutant parameters for each unit. Table 6-11 also includes cost information for these high-rate processes or devices. In the case where an existing plant is to be expanded or upgraded to handle storm flows, the TREATMENT FACILITY METHODOLOGY may be utilized to cost out the expansions/upgradings. The on-site treatment units listed in Table 6-11 do not include biological processes because of the difficulty of maintaining such a system with intermittent flows. However, biological treatment of storm flows by expanding existing biological plants is feasible, if an arrangement is made to provide necessary activated sludge from the dry-weather flow units, or by routing dry-weather flow through standby storm-flow units.

The user should consider providing the capability of increasing the loading on the primary settling tanks at existing wastewater treatment facilities. This may involve resetting the hydraulic regulators to allow more flow to enter the treatment plant, or increasing the pumping capacity at the head end of the treatment plant. This would accomplish several things. It would provide the capability of working off the wet-weather flows stored in upstream storm flow storage tanks more rapidly. It would also allow the collection system to be drawn down in order to provide more capacity for in-line storage, as was discussed under the COLLECTION SYSTEM CONTROL METHODOLOGY. The treatment efficiency of the primary settling tanks would be decreased, but the overall increase in loading to the stream could be less than if overflows were made necessary because of storage capacity (in the lines or in tanks) that was not available when the storm event occurred. Of course, it would also be necessary to provide bypasses after the primary tanks in case the secondary processes could not handle the increased flow.

Overflow - An overflow to the receiving water may come from a swirl separator, a storage (with settling) tank, or an on-site high-rate treatment unit. The user will want to make sure that the existing overflow line will handle the quantity of overflow anticipated. If state or local standards require disinfection, the cost of providing this disinfection must be included in the overall cost of the alternative.

Sludge Handling - An underflow or sludge is generated at the overflow site by a swirl separator, by storage with settling, or by on-site storm runoff treatment. The sludge may be treated on-site or may be transported via an interceptor to the existing wastewater treatment facility. Several sludge treatment processes may be used to treat the sludges on-site, as listed in worksheet Item 8. If this alternative is selected, provision must be made for transporting the treated sludge to a final disposal site. If the swirl separator or storage tank wastewater effluents are treated at the existing plant, then, of course, the sludges will also be handled at the plant.

If the sludges generated on-site are discharged to the interceptor in order to be treated at an existing wastewater treatment plant, several problems may arise. The first is related to the transportation of the sludges to the plant. The solids in storm flows are heavier than those in dry-weather flows, because the velocity of the stormwater in the sewer is usually greater than dry-weather velocities and will result in a scouring of previously deposited heavy solids. These solids will tend to settle out unless sufficient velocity is maintained in the interceptor to keep them suspended. Therefore, sections of the interceptor with marginal slopes might be subject to settling problems. Another potential problem associated with either on-site or at-plant treatment is the solids-handling capacity at the existing plant. For example, it has been estimated by EPA that the sludge load at a particular facility would be approximately doubled if combined sewer overflow sludges are directed to the plant. Therefore, the alternative of discharging sludges from sewer overflow storage and treatment components may include expanding the sludge-handling capacities at the existing treatment facility. The excess capacity of these units should be investigated when costing out this alternative. In addition, in the case of storm sewers it may be necessary to construct an interceptor from the overflow site to the nearest sanitary sewer interceptor in order to transport the sludges to the treatment plant.

A combination of the on-site and at-plant approaches is also feasible in some cases. Grit removal can be provided on-site to alleviate the heavy-solids transportation problem, and the sludge dewatering and additional treatment can take place at the existing wastewater treatment facility.

Step 3b (Item 4) - If the existing regulator in a combined sewer is to be replaced, or if a control device is to be installed in a storm sewer, the cost of a conventional regulator or swirl separator is calculated by using Table 6-11 or an equivalent method, and recorded in Item 4.

Step 3b (Item 5) - If the control option under consideration calls for on-site storage and direct discharge to the receiving water (without treatment either on-site or at the existing plant), Item 5 may be used for recording the cost of settling. If treatment is to be provided, Item 6 should be utilized in order to determine the least-cost combination of storage and treatment.

Step 3b (Item 6i) - Rainfall and stream flow are the driving forces behind all storm flow investigations. Since storm patterns and rainfall characteristics vary with geographic location, alternative methods of control must be considered.

Storms of high intensity and short duration may be controlled effectively by using storage facilities, whereas storms of low intensity and long duration may be controlled more effectively through increased treatment capacity or surface runoff deterrents. Intervals between storms are significant, because they may dictate dewatering requirements and in turn control treatment rates in a system clean-up between storms. Therefore, when dealing with storm events, the important characteristics are the intensity and type of precipitation, and the magnitude, frequency, and duration of the storm. These parameters may be determined by an investigation of rainfall records in the area of interest, by utilizing parameters already determined for nearby areas, or by any other appropriate method (see Chapter 3).

In order to determine the optimum (i.e., the least Present-Worth cost) mix of high-rate treatment and storage of storm flows, it is necessary to develop a hydrograph for the overflow from the control structure. Development of this overflow hydrograph involves identification of a design storm frequency, development of inlet (to the sewer system) hydrographs for the subarea tributary to an overflow structure, and use of a routing procedure to develop a composite hydrograph of the inflow to the control structure.

The design storm may be designated by a local drainage ordinance, or it may be determined by means of an engineering analysis. The choice of a design storm for a particular study area involves the following considerations:

- Timing of the rainfall and interval between events.
- Source data available.
- Scope and objectives of the investigation.
- Limitations of the physical system.

Engineering judgments relative to the most significant events for planning purposes can usually be made from available data.

Step 3b (Item 6ii) - Using the design storm event and the physical characteristics of the drainage area, the user must develop an inlet hydrograph for runoff from the subarea tributary to each outfall. Numerous hand and computer techniques are available for generating these hydrographs. The actual method applicable in a specific situation is left to the user's discretion.

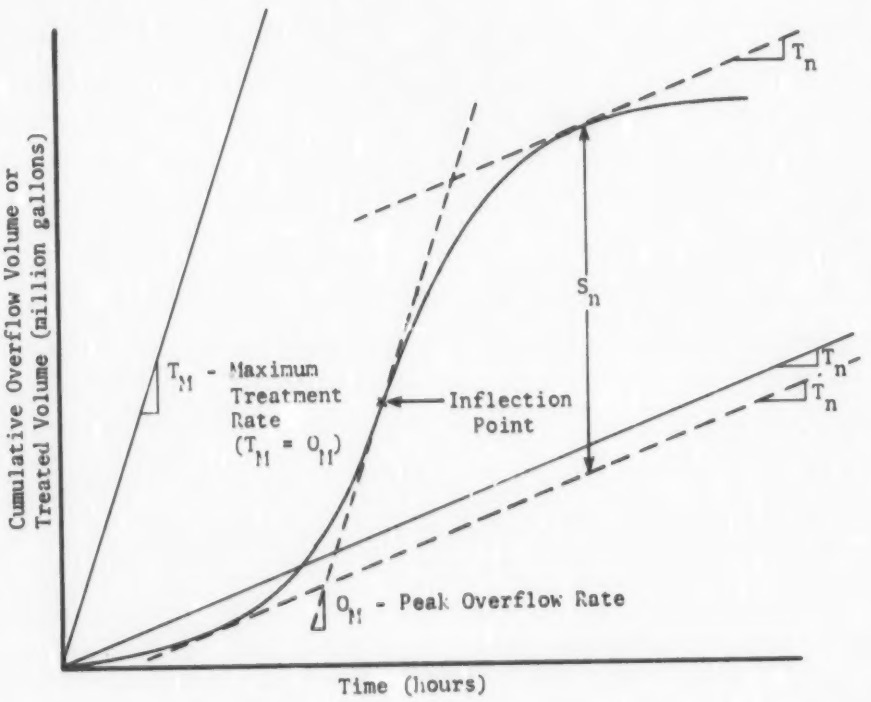
Step 3b (Item 6iii) - Having developed individual inlet hydrographs for each subarea, the user must now route the time-dependent flows to the overflow control structure in order to obtain a composite inflow hydrograph. During the routing procedure, the user should take into account available in-line storage capacity. The location and amount of available in-line storage can be determined by using the COLLECTION SYSTEM CONTROL METHODOLOGY.

Step 3b (Item 6iv) - Using this inflow hydrograph and a rating curve (i.e., head versus discharge) for the structure, the user can generate an overflow hydrograph.

Step 3b (Item 6v) - Assuming that all the overflow must be treated or stored for subsequent treatment, the user can identify storage requirements necessary for various treatment rates by using a mass curve developed directly from the overflow hydrograph. The time-specific flows of the hydrograph are converted to equivalent time-specific volumes and accumulated over the entire time span of the hydrograph. The cumulative volume at time T is obtained by taking the area under the overflow hydrograph to the left of time T. The cumulative volumes are plotted versus time as shown in Figure 6-20.

FIGURE 6-20

TYPICAL MASS DIAGRAM



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Step 3b (Item 6vi) - Using the mass curve, the user can determine the storage requirements for various treatment rates. The slope of the mass curve at any time is a measure of the overflow rate. Treatment rates can be represented by straight lines drawn from the origin. The storage volume required for a specific treatment rate can be obtained by drawing two tangents to the mass curve parallel to a desired treatment rate line and then measuring the vertical distance between the two lines.

The peak overflow rate (O_M) occurs at the inflection point of the mass diagram, which corresponds graphically to the maximum point on the inflow hydrograph. A treatment rate equal to the peak overflow rate would require no storage facilities. This rate is represented by the line with slope T_M ($T_M = O_M$). Lesser treatment rates would require storage of excess flows in order to prevent overflows. For example, for treatment rate T_N ($T_N < T_M$), storage S_N is required to prevent overflow.

The user can use the mass diagram to determine the storage requirements for treatment rates ranging from TM to no treatment, in convenient increments. These combinations of storage and treatment are the bases for identifying the least cost mix of storage and treatment.

Step 3b (Item 6vii) - The cost of the various levels of storage can be determined using the appropriate equation from Table 6-11, or an equivalent method. A plot should be made on standard graph paper of the volume to be stored and of the Present-Worth cost of storing that volume.

Step 3b (Item 6viii) - Table 6-11 can be used to determine the high-rate treatment units that can achieve the required load reductions. The cost of these units for the various treatment rates can be calculated by using the cost functions in Table 6-11. A plot of the cost of each type of unit for the range of treatment rates should be made on standard graph paper.

Step 3b (Item 6ix) - The user must also determine the costs associated with using existing wastewater treatment facilities in lieu of construction of on-site facilities. The various options to consider are discussed under Step 3a. The costs associated with treatment at the existing facility must be determined for each rate of treatment, using the TREATMENT FACILITY

METHODOLOGY when expansions or upgradings are necessary. The cost of transportation and treatment at each rate of treatment should be plotted on the same graph with the costs of on-site treatment (Item 6viii).

Step 3b (Item 6x) - The cost curves plotted in Items 6viii and 6ix can be used to determine the least-cost combination of storage and treatment rate in the following manner:

- For each treatment rate, identify the least-cost treatment unit (high-rate unit or existing plant expansion/upgrading from Item 6viii), and record the treatment cost.
- Identify the necessary storage volume for each rate of treatment (from Item 6vi), and record the cost of storage (from Item 6vii).
- Determine the total Present-Worth cost of storage and treatment for each treatment rate.
- Plot total Present-Worth Cost versus Treatment Rate on standard graph paper.

The minimum point on the curve will be the least-cost combination of storage and treatment.

Step 4a (Item 10) - The user should investigate the potential advantages of regionalization of storage/treatment facilities. Overflow locations are often in reasonably close proximity.

Depending on the specific situation, overflow points may be close enough to make the use of one large storage tank (or treatment unit, or both) an economical alternative.

6.4.2.8 Wastewater Reuse Methodology

Discussion

The purpose of this component methodology is to identify and evaluate potential wastewater reuse opportunities for a specific point source. The initial step is to identify whether there is a reuse potential in the planning area. When reuse seems feasible, the potential reuse candidates and their water quality requirements are identified. The additional cost to achieve a treatment level beyond that required for discharge, if necessary, is evaluated by means of other component methodologies included in this manual or equivalent methods. The wastewater transportation cost is also identified, and the total cost for treatment and reuse is determined. The reuser's cost for the existing water supply or the development cost for a new supply is then determined and compared with the additional cost incurred by the reuser for wastewater reuse. This evaluation will indicate if an economic incentive exists for wastewater reuse, as indicated by a potential saving to the reuser.

This methodology does not deal with pricing policies for wastewater reuse. This is a specific consideration for any potential reuse application, and is complex because of the interaction of supply and demand. However, the determination of the potential economic incentive for reuse accomplished in this methodology should be adequate for identifying the potential for wastewater reuse revenues.

Finally, this methodology can be readily modified to handle the case where more than one reuser exists for a point source. The 208 planner or engineer can do this by beginning his evaluation with the potential reuser who has the most stringent water quality requirement. The wastewater from this alternative could then be used by any subsequent reuser in the planning area, so that only the transportation cost would have to be computed. Another approach would be to combine several potential reusers for one evaluation. By utilizing these concepts, the 208 planner or engineer can readily develop the cost associated with several reuse schemes and at the same time minimize his effort in identifying treatment facility costs.

Methodology Logic

A summary of Methodology Logic is presented in Figure 6-21. An expanded flowchart, Figure 6-22, lists the steps to be taken in determining performance and costs. The worksheets for recording the operations are presented as Table 6-12. Notes on specific steps or worksheet items are included after the worksheet.

FIGURE 6-21

WASTEWATER REUSE METHODOLOGY
LOGIC SUMMARY

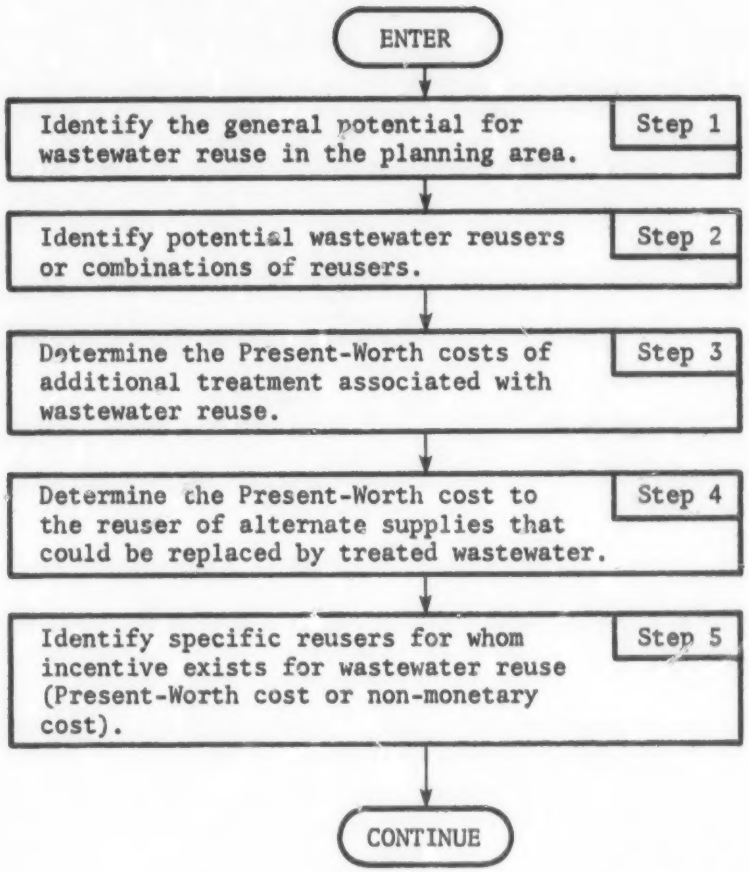
ENTER
Identify the general potential for wastewater reuse in the planning area.
Step 1
Identify potential wastewater reusers or combinations of reusers.
Step 2
Determine the Present-Worth costs of additional treatment associated with wastewater reuse.
Step 3
Determine the Present-Worth cost to the reuser of alternate supplies that could be replaced by treated wastewater.
Step 4
Identify specific reusers for whom incentive exists for wastewater reuse (Present-Worth cost or non-monetary cost).
Step 5
CONTINUE

FIGURE 6-22

WASTEWATER REUSE METHODOLOGY
FLOWCHART

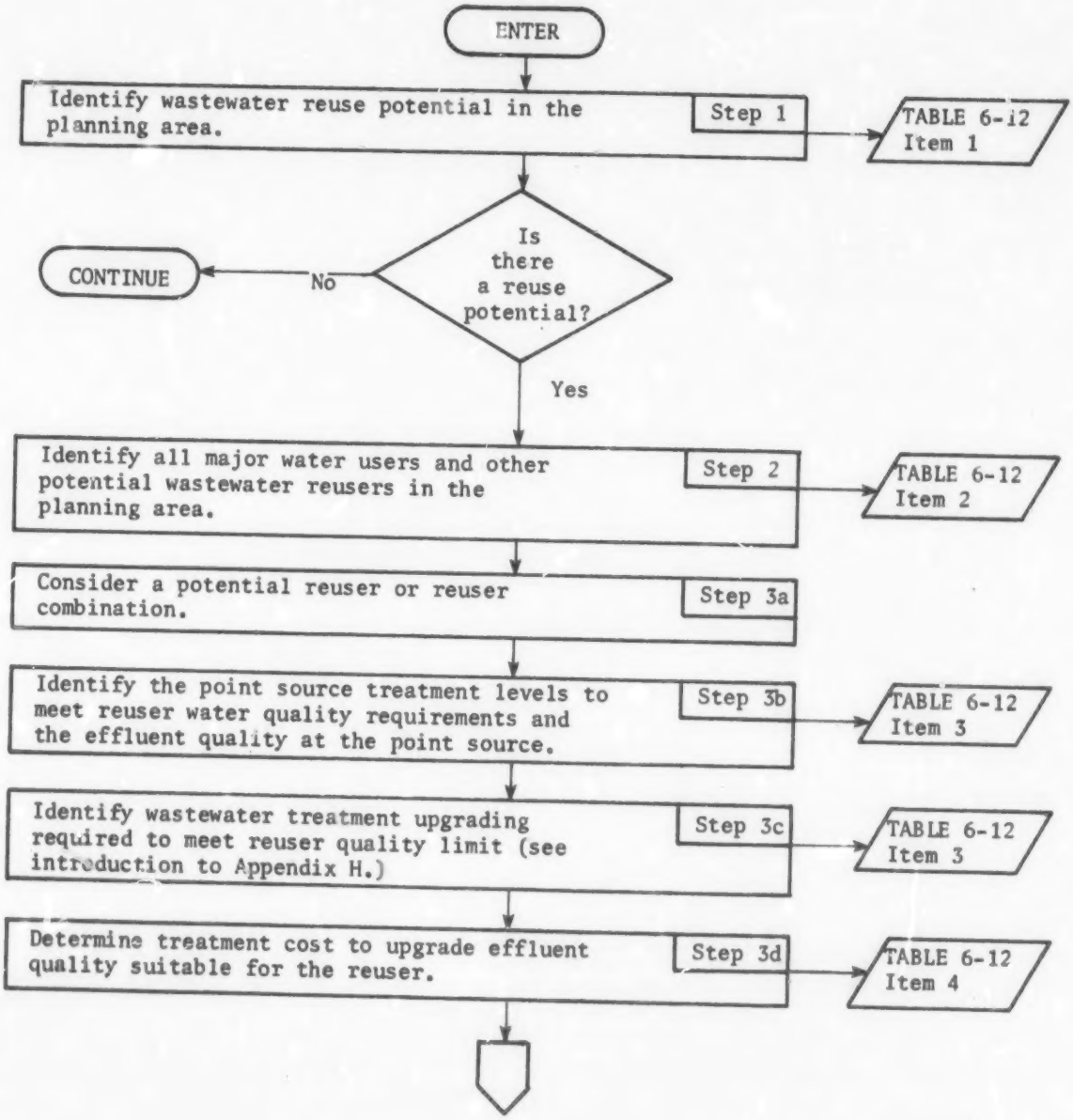
ENTER
Identify wastewater reuse potential in the planning area.
Step 1
TABLE 6-12 Item 1
Is there a reuse potential?
No
CONTINUE
Yes
Identify all major water users and other potential wastewater reusers in the planning area.
Step 2
TABLE 6-12 Item 2
Consider a potential reuser or reuser combination.
Step 3a
Identify the point source treatment levels to meet reuser water quality requirements and the effluent quality at the point source.
Step 3b
TABLE 6-12 Item 3
Identify wastewater treatment upgrading required to meet reuser quality limit (see introduction to Appendix H.)
Step 3c
TABLE 6-12 Item 3
Determine treatment cost to upgrade effluent quality suitable for the reuser.
Step 3d
TABLE 6-12 Item 4

FIGURE 6-22 (CONTINUED)

WASTEWATER REUSE METHODOLOGY
FLOWCHART

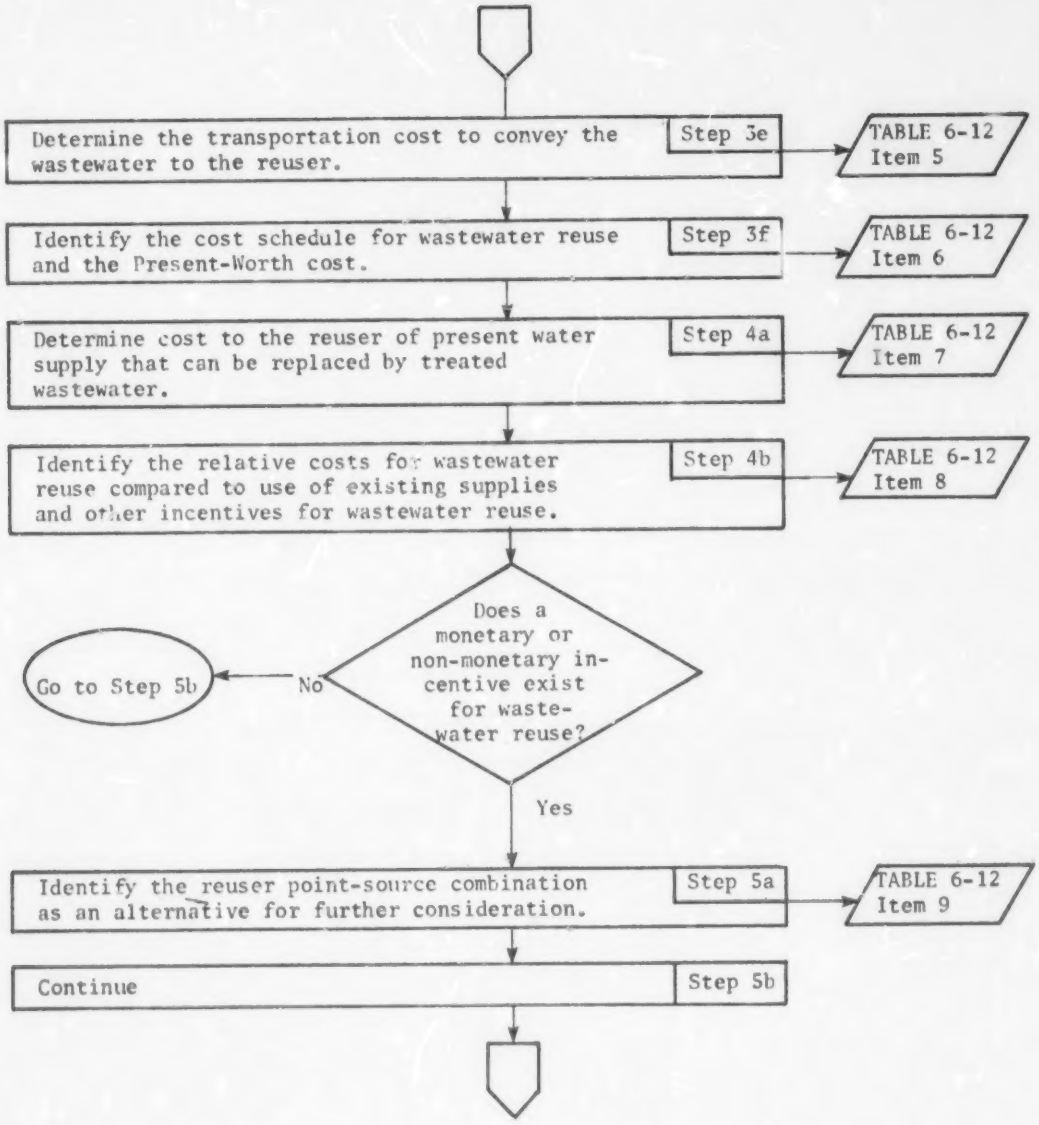
Determine the transportation cost to convey the wastewater to the reuser.
Step 3e
TABLE 6-12 Item 5
Identify the cost schedule for wastewater reuse and the Present-Worth cost.
Step 3f
TABLE 6-12 Item 6
Determine cost to the reuser of present water supply that can be replaced by treated wastewater.
Step 4a
TABLE 6-12 Item 7
Identify the relative costs for wastewater reuse compared to use of existing supplies and other incentives for wastewater reuse.
Step 4b
TABLE 6-12 Item 8
Does a monetary or non-monetary incentive exist for wastewater reuse?
No
Go to Step 5b
Yes
Identify the reuser point-source combination as an alternative for further consideration.
Step 5a
TABLE 6-12 Item 9
Continue
Step 5b

FIGURE 6-22 (CONTINUED)

WASTEWATER REUSE METHODOLOGY
FLOWCHART

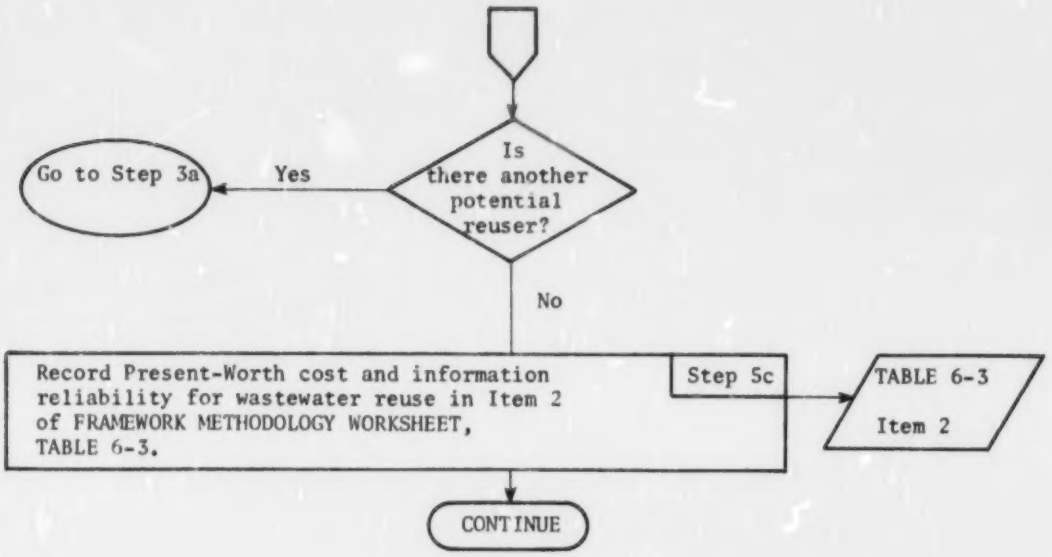
Is there another potential reuser?
Yes
Go to Step 3a
No
Record Present-Worth cost and information reliability for wastewater reuse in Item 2 of FRAMEWORK METHODOLOGY WORKSHEET, TABLE 6-3.
Step 5c
TABLE 6-3
Item 2
CONTINUE

TABLE 6-12 (continued)
WASTEWATER REUSE METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgments presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach available (or even as the preferred approach). However, any approach used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other EPA, State, and local guidelines and regulations.

Item 1 - General Reuse Criteria.

i.	Total municipal water demand approaching existing water supply?	YES	NO
ii.	Existing water supplies unavailable or insufficient for new uses (e.g., irrigation, industry)?	YES	NO
iii.	Existing water supply subject to environmental degradation (e.g., salt water intrusion, aquifer drawdown)?	YES	NO
iv.	Point source wastewater effluent available in sufficient quantity to satisfy potential new needs?	YES	NO
v.	Point source disposal technique involves unusually high costs?	YES	NO
vi.	Planning area includes any large uses of non-potable water?	YES	NO
vii.	Absence of restrictions (riparian rights) or related water law?	YES	NO
viii.	Expressed interest on the part of potential wastewater reusers?	YES	NO

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TABLE 6-12 (continued)
WASTEWATER REUSE METHODOLOGY
WORKSHEET

Item 2 - Potential Reuse Source Identification

Potential Water Reuser Identification	Water Source/ Treatment	Water Use	Present Water Cost	Projected Water Cost	Quantity		Quality		Reliability	Distance
					Current	Design Yr	Desired	Minimum		
EXAMPLE:										
1. Georgia Power Plant, Mitchell. Mr. John Phillips Plant Engineer	Flint River/ screened, settled.	Cooling Water	$0.12/1000 gal	$0.24	1.4 mgd (0.6 mgd firm minimum)	1.4 mgd (1985)	76°F pH, 7.2	84°F pH 7.0-7.8	complete	3 miles, across Flint River
2. Blue Valley Pecan Farm. Mr. Tom Young Owner	Private well, no treatment	Irrigation	$.08/1000 gal pumping cost	$0.22	400,000 gpd (May-Nov)		No toxic metals, low dissolving solids, normal pH	same	low	2 miles
Albany County Club	Private well, no treatment	Irrigation	$.14/1000 gal pumping cost	$0.38	300,000 gpd (May-Nov)	700,000 gpd (1980)	same		low	8 miles

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TABLE 6-12 (continued)
WASTEWATER REUSE METHODOLOGY
WORKSHEET

POTENTIAL REUSER EVALUATION
Reuser: _____

Item 3 - Point Source Treatment to Meet Reuse Criteria.

	Reference Cost Curve	Reuser/Point Source Critical Parameters							
		Q	BOD	TSS	N	P	T		
Reuser Water Quality Requirements	N/A								
Existing Wastewater Effluent Quality									
Existing Wastewater Effluent Quality Control Criteria									
Upgrade Technique[1]									

[1]Identify the cost curve for upgrading each identified parameter to the reuser criterion; identify the required system under "Reference Cost Curve" from individual curves.

Item 4 - Treatment Requirement Cost Schedule to Meet Reuser Criteria.

(Use TREATMENT FACILITY METHODOLOGY to define costs for treatment above that required for discharge)

Phase	Timing		Capital	O&M		Replacement Cost		Salvage
	Yr.	to Yr.		Start	End	Year	Cost	Value
Existing Facility								
1								
2								
3								
n								

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TABLE 6-12 (continued)
WASTEWATER REUSE METHODOLOGY
WORKSHEET

Item 5 - Reuse Transportation Cost Schedule.

Phase	Timing Yr. to Yr.		Capital	O&M Start	O&M End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Existing Facility								
1								
2								
3								
n								

Item 6 - Wastewater Reuse Project Costs.

i. Project Cost Schedule.

Phase	Timing Yr to Yr	Item	Capital Cost	Start O&M	End O&M	Variable O&M	Salvage Value
1		#4					
		#5					
			____	____	____	____	____
	TOTAL PHASE 1						
2		#4					
		#5					
			____	____	____	____	____
	TOTAL PHASE 2						
3		#4					
		#5					
			____	____	____	____	____
	TOTAL PHASE 3						

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TABLE 6-12
WASTEWATER REUSE METHODOLOGY
WORKSHEET

Item 6 - Wastewater Reuse Project Costs (continued).

Phase	Timing Yr to Yr	Item	Capital Cost	Start O&M	End O&M	Variable O&M	Salvage Value
n		#4					
		#5					

TOTAL PHASE n

Replacement Schedule Year	Cost

ii. Present-Worth Cost (using PRESENT WORTH METHODOLOGY).

Interest _____%

Present-Worth Cost $_____

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TABLE 6-12 (continued)
WASTEWATER REUSE METHODOLOGY
WORKSHEET

Item 7 - Reuser Replaceable Water Costs.
(Cost that would be incurred for replaceable water supply without wastewater recycle)

i. Cost Schedule.

Phase	Timing Yr to Yr	Recycle Water Use[1], gpd Start	Recycle Water Use[1], gpd End	Unit Water Cost[2] $/1000 gal	Annual Water Cost[3], $/year Start	Annual Water Cost[3], $/year End
1						
2						
3						
n						

[1]Recycle Water Use represents the portion of total reuser water requirement that could be satisfied by treated wastewater.
[2]Unit Water Cost represents projected cost for existing supply if adequate, or the unit cost for development and treatment of a new supply.
[3]Annual Water Cost = (gpd) ($/gal) (365 days/yr)

ii. Reuser Replaceable Water Present-Worth Cost.
(using PRESENT-WORTH METHODOLOGY): $_____

Item 8 - Wastewater Reuser Relative Costs.

i. Replaceable Water Cost: $_____
(Alternative Present-Worth cost for reuser water needs that can be satisfied during the planning period by treated wastewater; from Item 7 ii)

ii. Reused Wastewater Cost: $_____
(Present-Worth cost to utilize treated wastewater; from Item 6 ii)

iii. Other Factors: (describe factors other than cost that will affect further evaluation)

_____

_____

_____

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TABLE 6-12 (continued)
WASTEWATER REUSE METHODOLOGY
WORKSHEET

Item 9 - Potential Reuser/Point-Source Combinations

Point Source		Reuser		Identified Present-Worth Costs			
ID	Q,mgd	ID	Q,mgd	Wastewater Reuse	Replaceable Water	Total	Non-Monetary Cost Incentive

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Notes on Methodology Logic

Step 1 (Item 1) - The purpose of this step is to determine if there is a reuse potential in the planning area. This might occur where the available water supply limits current or future water demand, where the existing water supply will be subject to environmental degradation due to overuse or the impact of the wastewater discharge, where the wastewater effluent is of a high quality, or where wastewater disposal is unusually expensive. If any of the situations identified in Item 1 exist, then the user of this manual should evaluate the wastewater reuse potential further.

Step 2 (Item 2) - This step will identify the potential reusers in the planning area and also potential new uses for wastewater. A guideline is included in Table 6-13, which identifies some potential reusers. The information for each potential reuser is entered in Item 2. The information developed for reuse of effluent from one point source in the planning area will likely be applicable for the evaluation of wastewater reuse at other point sources.

Step 3a - No discussion.

Step 3b (Item 3) - The purpose of this step is to identify the required level of treatment for utilization of the wastewater to supplement or replace the reuser water supply. The critical water quality parameters for the specific reuser should be identified in the worksheet as completely as possible. One source for this information is reference (11).

The existing wastewater discharge quality can be identified using the method outlined in the TREATMENT FACILITY METHODOLOGY. Any additional treatment required to meet the reuser's needs is identified for each critical parameter. If the required water quality for the reuser is not greater than that for wastewater discharge, then there will not be an increased treatment cost.

Step 3c (Item 3) - In this step, the upgrading technique to meet the reuser's water quality requirements is determined. The user should incorporate information in Appendix H (or comparable sources) regarding the effluent characteristics from alternative treatment processes.

Step 3d (Item 4) - This step identifies the treatment cost schedule for the modification required to meet the reuser's water quality requirements. The

TABLE 6-13

POTENTIAL CUSTOMERS AND APPLICATIONS
FOR WASTEWATER REUSE

Customer	Applications
Municipal	Irrigation - Public parks, zoo grounds, government centers, etc. - Public golf courses - School grounds - Publicly-owned farm lands - Right-of-way landscaping - Other
	Groundwater recharge
	Prevention of salt water intrusion
	Recreational lakes
	Public utilities - Cooling water for power plants
Private Industry	Cooling water
	Boiler feed water
	Process purposes
	Irrigation of grounds
Private Irrigation	Crop irrigation
	Salt leaching
	Irrigation of - Golf courses - Duck clubs - Recreational areas, including artificial lakes

*This list is not all inclusive; the individual planning agency should develop a similar listing specific to the planning area.

planner can utilize the TREATMENT FACILITY METHODOLOGY to determine the treatment cost involved in attaining this level of treatment when a general treatment facility upgrading is required. If only a portion of the wastewater flow is utilized for reuse or if only one additional treatment operation is required to upgrade the wastewater quality to meet the reuser's need, then the capital cost can be developed using the TREATMENT FACILITY METHODOLOGY, or an equivalent method, with the required adjustments for construction costs.

Step 3e (Item 5) - In this step, the transportation cost schedule for pumping the required wastewater quantity to the reuser is determined by means of the TRANSPORTATION COST METHODOLOGY.

Step 3f (Item 6) - In this step, the transportation and reuse treatment costs schedules are combined to determine the total project cost schedule. The project present-worth cost can be determined by means of the PRESENT-WORTH METHODOLOGY.

Step 4a (Item 7) - In this step, the cost to the potential wastewater reuser for replaceable water during the planning period is determined. The quantity of replaceable water should represent the portion of the reuser's need that can be satisfied by treated wastewater. Where the reuser's current supply will be inadequate for future needs, the unit cost for developing and treating a new supply should be used.

Step 4b (Item 8) - This step determines if there is an economic incentive for wastewater reuse. Since a potential reuser would not be willing to pay more for the treated wastewater than for the water supply currently used, the maximum revenues from wastewater reuse to the treatment plant control authority will always be less than this current water supply cost. Therefore, the control authority will not find it cost-effective to pursue treatment and reuse where the reuse cost is greater than the current water supply cost, unless other factors (such as a limited water supply) outweigh the monetary cost considerations.

Step 5a - This step is a summary of the potentially cost effective point source/reuser combinations. When the wastewater reuse evaluation has been completed, this list will be useful in ordering priorities for future investigations and for assessing the overall potential for reuse.

6.4.2.9 Impact Area Modification Methodology

Discussion

An impact area modification involves an alteration of the natural characteristics of the receiving water body, such as in-stream reaeration, low-flow augmentation, or a change in the physical location of a discharge point. Reducing the impact of a pollutant discharge is sometimes less expensive than reducing the pollution load in the discharge. This might also be the only feasible alternative remaining if all feasible pollutant load reduction alternatives have already been implemented. In addition, this alternative may also be especially applicable in certain streams where flow is highly regulated. This component methodology will identify the monetary costs associated with several modification schemes: discharge relocation, in-stream reaeration, and flow augmentation.

The initial determination in this evaluation is the desired and critical water quality of the receiving streams. These stream segments are commonly classified as: 1) Effluent Limited (implying that the control level is based on the generally accepted treatment level); or 2) Water Quality Limited (which means that the effluent control level has been based on a waste load allocation calculated as necessary to maintain the desired water quality). The IMPACT AREA MODIFICATION METHODOLOGY is generally more often applicable to Water Quality Limited stream segments, since these tend to have the more stringent treatment requirements.

Discharge relocation is probably the most feasible of the impact area modifications in this evaluation procedure. The required procedure involves identification of alternative discharge sites and evaluation of the points of relocation. The water quality impact analysis techniques described in Chapter 5 must be performed for the modified loading pattern to define the required treatment level at the proposed new location. Then, the costs of treatment and transporation are computed.

In-stream reaeration will be a feasible technique only when the dissolved oxygen in the receiving water is a critical water quality parameter and where aeration is compatible with physical stream characteristics. Chapter 5 techniques are required in this evaluation to redefine the source treatment

level. Then, the cost to implement the reaeration system and the cost for the modified treatment control level are evaluated.

Flow augmentation should be considered when water quality standards are violated during low-flow conditions, when means for flow augmentation (such as an upstream reservoir) are available, and when low-flow augmentation will alleviate one or more critical water quality parameters. The methodology guides the user in identifying the flow-augmentation capability in determining the allowable waste loads with the flow augmented, and finally in evaluating all project costs including treatment costs and flow-augmentation costs.

The user should be advised that current EPA policy will not permit use of flow augmentation as a substitute for "adequate treatment". See reference (19). Thus, flow augmentation may only be considered where water quality standards are not met through Best Available Technology (BAT) level of treatment. Even where flow augmentation is warranted, the user should be aware of potential institutional difficulties in securing flow release guarantee agreements with agencies controlling watercourses. The user should also consider potential adverse effects of flow augmentation upon other uses of dams and reservoirs (e.g., water-based recreation, water supply, power generation).

Methodology Logic

A summary of the logic of the IMPACT AREA MODIFICATION METHODOLOGY is presented in Figure 6-23. An expanded flowchart, Figure 6-24, lists the steps to be taken in determining performance and costs. The worksheets for recording the operations are presented as Table 6-14. Notes on specific steps or worksheet items are presented after the worksheets.

FIGURE 6-23

IMPACT AREA MODIFICATION METHODOLOGY
LOGIC SUMMARY

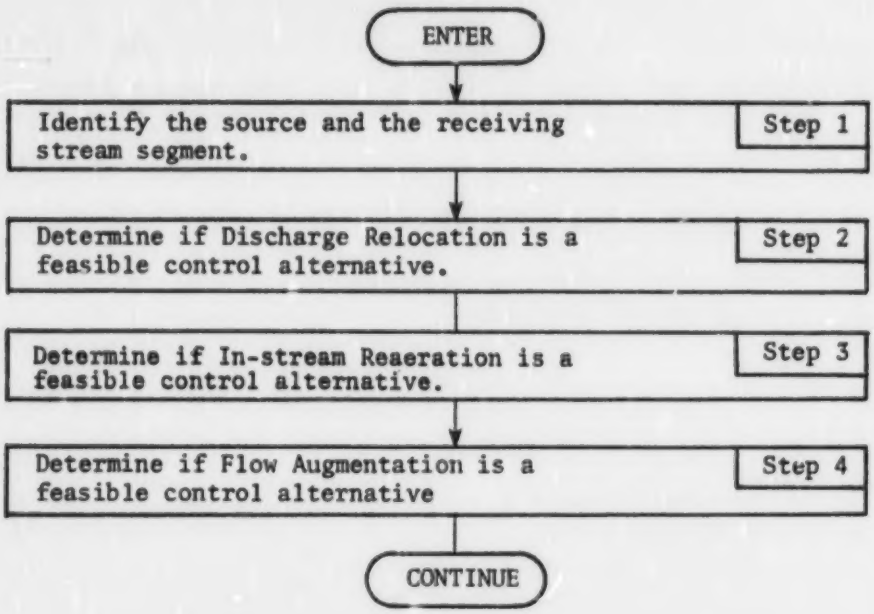
ENTER
Identify the source and the receiving stream segment.
Step 1
Determine if Discharge Relocation is a feasible control alternative.
Step 2
Determine if In-stream Reaeration is a feasible control alternative.
Step 3
Determine if Flow Augmentation is a feasible control alternative
Step 4
CONTINUE

FIGURE 6-24

IMPACT AREA MODIFICATION METHODOLOGY
FLOWCHART

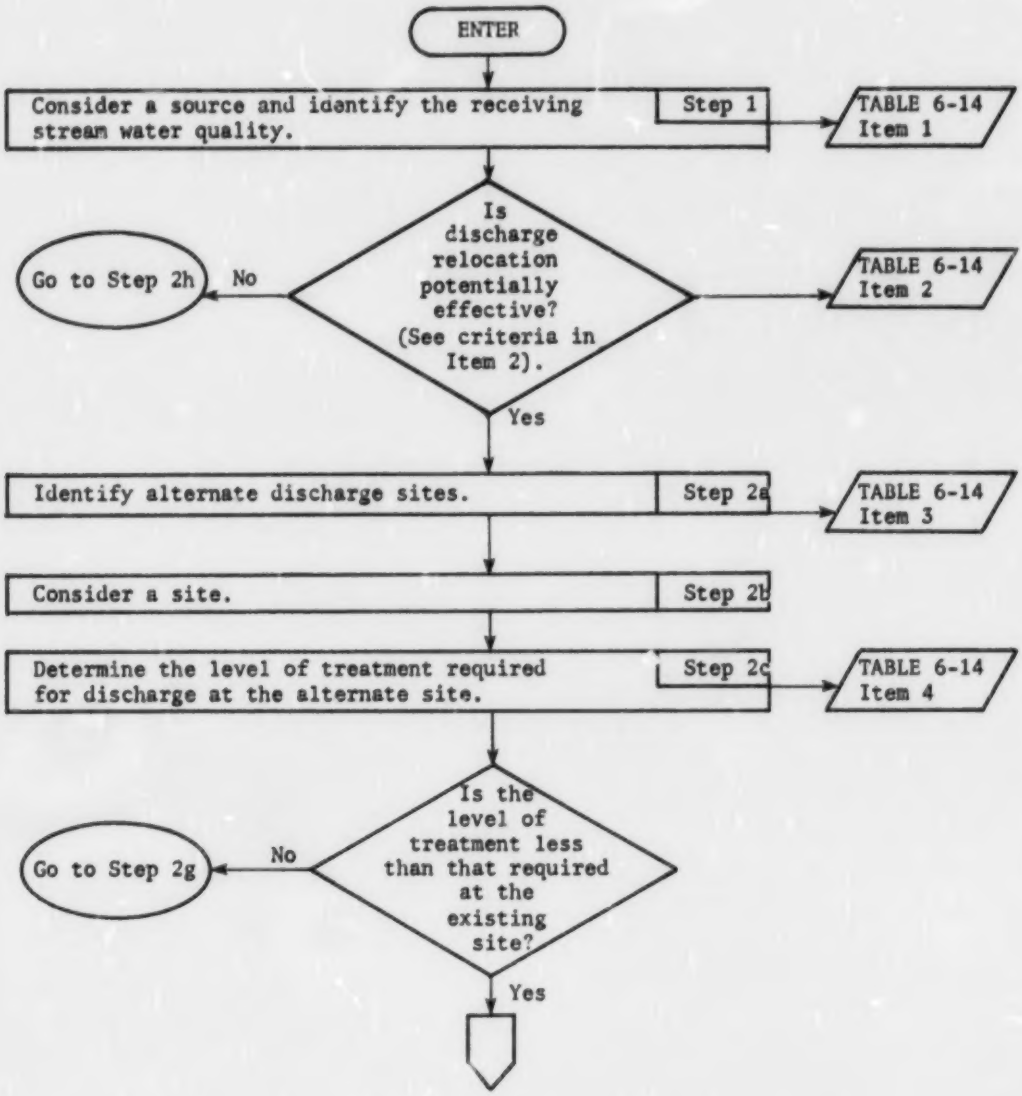
ENTER
Consider a source and identify the receiving stream water quality.
Step 1
TABLE 6-14 Item 1
Is discharge relocation potentially effective? (See criteria in Item 2).
No
Go to Step 2h
TABLE 6-14 Item 2
Yes
Identify alternate discharge sites.
Step 2a
TABLE 6-14 Item 3
Consider a site.
Step 2b
Determine the level of treatment required for discharge at the alternate site.
Step 2c
TABLE 6-14 Item 4
Is the level of treatment less than that required at the existing site?
No
Go to Step 2g
Yes

FIGURE 6-24 (CONTINUED)

IMPACT AREA MODIFICATION METHODOLOGY
FLOWCHART

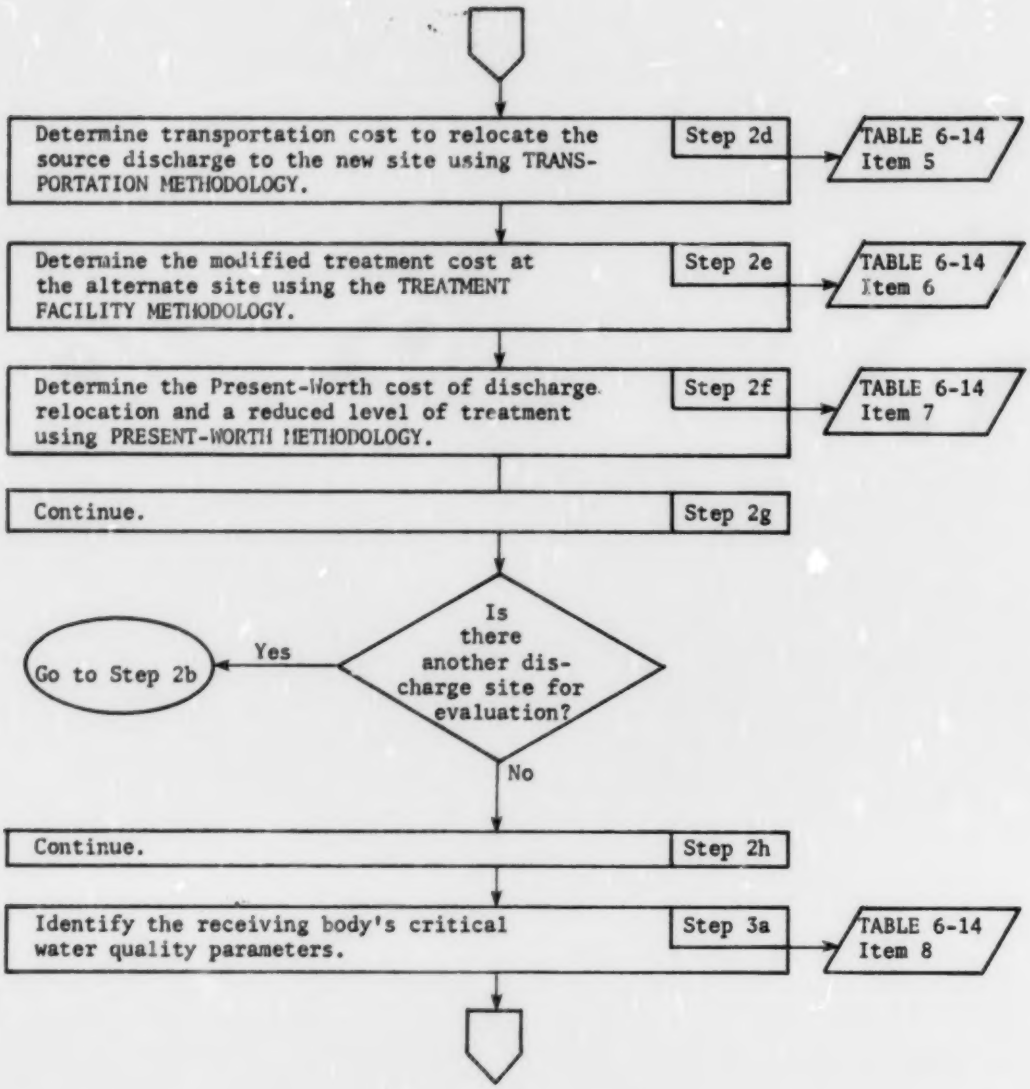
Determine transportation cost to relocate the source discharge to the new site using TRANSPORTATION METHODOLOGY.
Step 2d
TABLE 6-14 Item 5
Determine the modified treatment cost at the alternate site using the TREATMENT FACILITY METHODOLOGY.
Step 2e
TABLE 6-14 Item 6
Determine the Present-Worth cost of discharge relocation and a reduced level of treatment using PRESENT-WORTH METHODOLOGY.
Step 2f
TABLE 6-14 Item 7
Continue.
Step 2g
Is there another discharge site for evaluation?
Yes
Go to Step 2b
No
Continue.
Step 2h
Identify the receiving body's critical water quality parameters.
Step 3a
TABLE 6-14 Item 8

FIGURE 6-24 (CONTINUED)

IMPACT AREA MODIFICATION METHODOLOGY
FLOWCHART

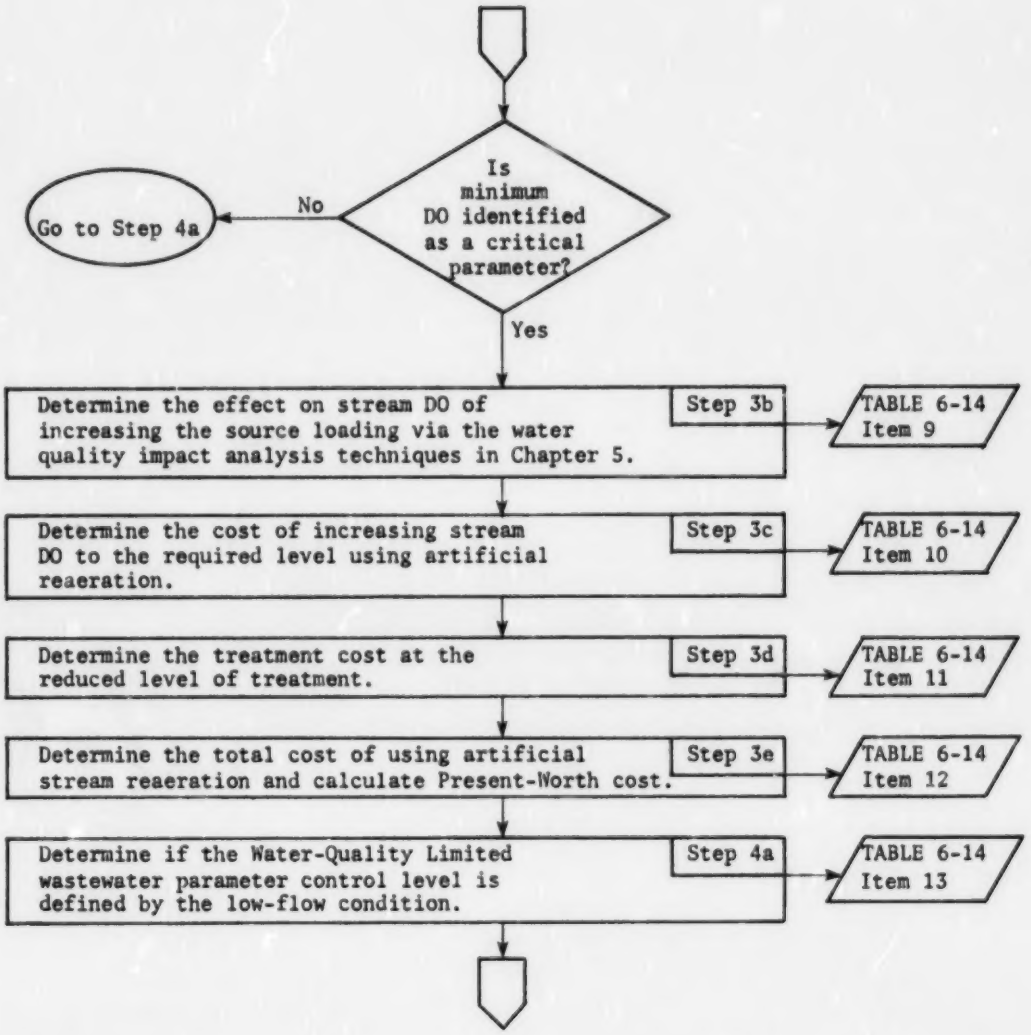
Is minimum DO identified as a critical parameter?
No
Go to Step 4a
Yes
Determine the effect on stream DO of increasing the source loading via the water quality impact analysis techniques in Chapter 5.
Step 3b
TABLE 6-14 Item 9
Determine the cost of increasing stream DO to the required level using artificial reaeration.
Step 3c
TABLE 6-14 Item 10
Determine the treatment cost at the reduced level of treatment.
Step 3d
TABLE 6-14 Item 11
Determine the total cost of using artificial stream reaeration and calculate Present-Worth cost.
Step 3e
TABLE 6-14 Item 12
Determine if the Water-Quality Limited wastewater parameter control level is defined by the low-flow condition.
Step 4a
TABLE 6-14 Item 13

FIGURE 6-24 (CONTINUED)

IMPACT AREA MODIFICATION METHODOLOGY
FLOWCHART

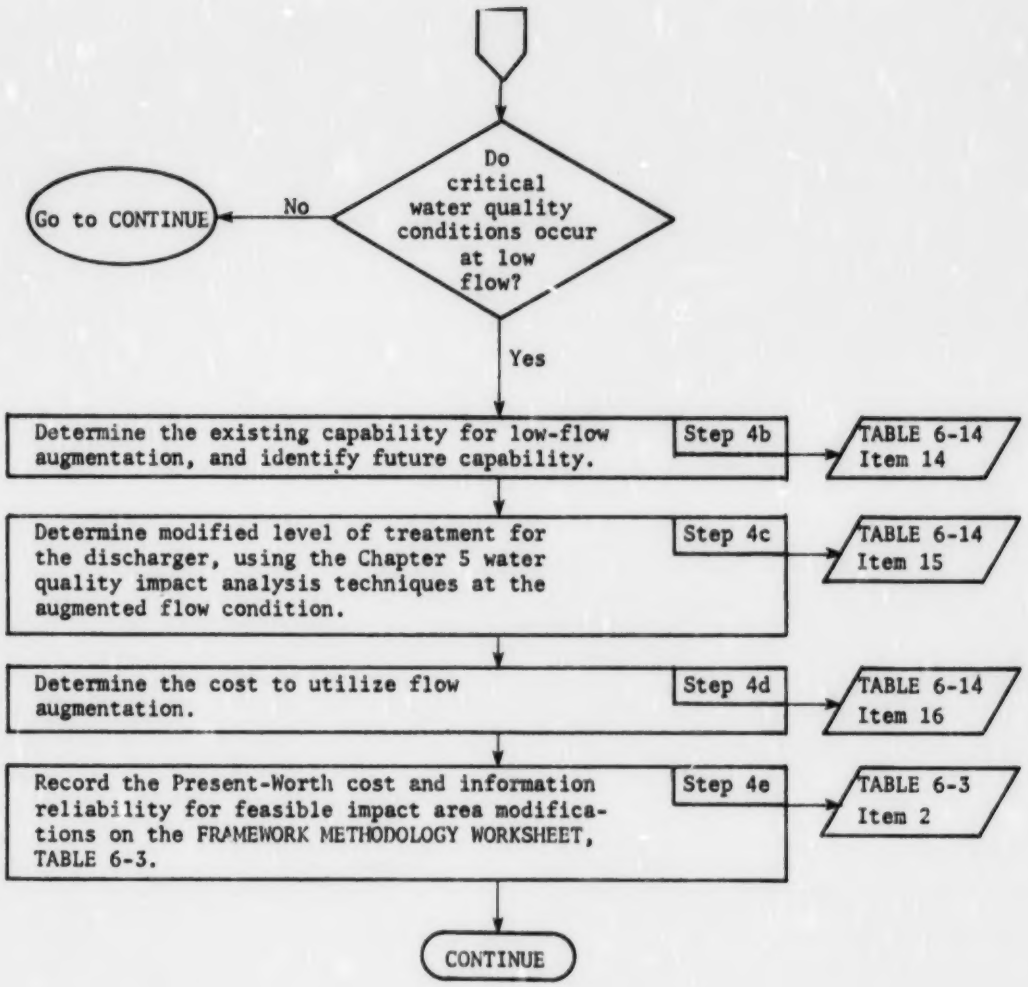
Do critical water quality conditions occur at low flow?
No
Go to CONTINUE
Yes
Determine the existing capability for low-flow augmentation, and identify future capability.
Step 4b
TABLE 6-14 Item 14
Determine modified level of treatment for the discharger, using the Chapter 5 water quality impact analysis techniques at the augmented flow condition.
Step 4c
TABLE 6-14 Item 15
Determine the cost to utilize flow augmentation.
Step 4d
TABLE 6-14 Item 16
Record the Present-Worth cost and information reliability for feasible impact area modifications on the FRAMEWORK METHODOLOGY WORKSHEET, TABLE 6-3.
Step 4e
TABLE 6-3 Item 2
CONTINUE

TABLE 6-14
IMPACT AREA MODIFICATION METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgments presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach available (or even as the preferred approach). However, any approach used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other EPA, State, and local guidelines and regulations.

Item 1 - Receiving Water Quality.

Source _____

Water Quality Conditions: (Summary of existing and future water quality problems by pollutant type for stream segment of interest)

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

TABLE 6-14
IMPACT AREA MODIFICATION METHODOLOGY
WORKSHEET

Discharge Relocation Evaluation.

Item 2 - General Criteria for Discharge Relocation.

1. Is this source a principal cause of the critical stream condition? YES NO

2. Are there several significant sources near this source? YES NO

3. Would relocation be relatively inexpensive? YES NO

4. Is there a major (or larger) stream nearby that could receive the source? YES NO

Item 3 - Alternate Discharge Site Identification.

(Factors: Less stringent water quality criteria; lower net source loading; increased dilution due to tributary flow)

	Site	Location	Distance
a)			
b)			
c)			

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

TABLE 6-14 (CONTINUED)
IMPACT AREA MODIFICATION METHODOLOGY
WORKSHEET

Site _____ Evaluation

Item 4 - Modified Source Level of Treatment (from Impact Analysis, Chapter 5).

Level	Reference Cost Curve	Parameter Control Levels							
		BOD mg/l	COD mg/l	TSS mg/l	T-P mg/l	NH_3-N mg/l	NO_3-N mg/l	T-N mg/l	T-C #/100ml
Existing Discharge Site									
Alternate Discharge Site A									
Alternate Discharge Site B									

Item 5 - Discharge Relocation Transportation Cost Schedule.
(use the TRANSPORTATION COST METHODOLOGY)

Phase	Timing Yr. to Yr.		Capital	O&M Start	O&M End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Existing Facility								
1								
2								
3								
n								

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

TABLE 6-14 (CONTINUED)
IMPACT AREA MODIFICATION METHODOLOGY
WORKSHEET

Item 6 - Modified Treatment Level Cost Schedule.
(use TREATMENT FACILITY METHODOLOGY)

Phase	Timing Yr. to Yr.		Capital	O&M Start	O&M End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Existing Facility								
1								
2								
3								
n								

Item 7 - Project Cost.

i. Project Cost Schedule.

Phase	Timing Yr. to Yr.		Capital	O&M Start	O&M End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Existing Facility								
1								
2								
3								
n								

ii. Project Present-Worth Cost: $_____
(use PRESENT-WORTH METHODOLOGY)

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

TABLE 6-14 (CONTINUED)
IMPACT AREA MODIFICATION METHODOLOGY
WORKSHEET

ARTIFICIAL REAERATION EVALUATION

Item 8 - Receiving-Body Dissolved Oxygen Requirements.

Condition	Dissolved Oxygen, mg/l	@	Location
Water Quality Limit	_____		_____
Critical Level	_____		_____

Item 9 - Modified Stream Quality at Revised Source Loads.
(developed from Impact Analysis, Chapter 5)

	Wastewater Load Parameter	Discharge Level	Resulting Minimum Stream DO	@	Location
A.	BOD	_____	_____	@	_____
	TSS	_____			
	(etc.)	_____			
B.	BOD	_____	_____	@	_____
	TSS	_____			
	(etc.)	_____			

Item 10 - Artificial Reaeration Requirement.

i. Oxygen-Transfer Requirements.

Stream flow rate at critical conditions: _____cfs

Critical DO level: _____mg/l

Minimum acceptable DO level: _____mg/l

Oxygen transfer requirement: _____lb/hr for _____hr/yr

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

TABLE 6-14 (CONTINUED)
IMPACT AREA MODIFICATION METHODOLOGY
WORKSHEET

Item 10 - Artificial Reaeration Requirement (continued).

ii. Reaeration Project Phasing.

Phase	Timing Yr to Yr		Reaeration Oxygen Demand, lb/hr Start	End	Capital	O&M Start	O&M End	Replacement Cost	Salvage Value
1									
2									
3									
n									

Item 11 - Treatment Cost Schedule at Modified Treatment Level.

Phase	Timing Yr. to Yr.		Capital	O&M Start	O&M End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Existing Facility								
1								
2								
3								
n								

Item 12 - Artificial Reaeration Project Cost.

i. Project Cost Schedule.

Phase	Timing Yr. to Yr.		Capital	O&M Start	O&M End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Existing Facility								
1								
2								
3								
n								

ii. Project Present-Worth Cost: $_____

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

TABLE 6-14 (CONTINUED)
IMPACT AREA MODIFICATION METHODOLOGY
WORKSHEET

FLOW AUGMENTATION EVALUATION

Item 13 - General Applicability of Flow Augmentation as a feasible control alternative.

Do critical water quality conditions occur at low flow?
(Yes or no) _____ Critical Parameters, if yes; _____

Comments: (Special conditions, model assumptions, reference sheets)

_____

_____

_____

Item 14 - Flow-Augmentation Capability.

i. Existing Reservoir low-flow augmentation capacity: _____cfs
Duration: _____days

ii. Proposed Reservoir low-flow augmentation capacity: _____cfs
Duration: _____days

Item 15 - Modified Source Load Control with Flow Augmentation.

i. Available Flow for Augmentation for the required duration _____cfs

ii. Revised stream low flow _____cfs

iii. Revised Level of Treatment

	Critical Parameter	Revised Control Level
a)	_____	_____
b)	_____	_____

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

TABLE 6-14 (CONTINUED)
IMPACT AREA MODIFICATION METHODOLOGY
WORKSHEET

Item 16 - Flow Augmentation Cost

i. Modified Level of Treatment Cost Schedule.

Phase	Timing Yr. to Yr.		Capital	O&M Start	O&M End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Existing Facility								
1								
2								
3								
n								

ii. Flow Augmentation Cost Schedule.

Phase	Timing Yr. to Yr.		Capital	O&M Start	O&M End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Existing Facility								
1								
2								
3								
n								

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

TABLE 6-14 (CONTINUED)
IMPACT AREA MODIFICATION METHODOLOGY
WORKSHEET

Item 16 - Flow Augmentation Cost (continued).

iii. Project Cost Schedule.

Phase	Year to Year	Item	Capital Cost	Start O&M	End O&M	Variable O&M	Salvage Value
1		16i					
		16ii					
	Total Phase 1						
2		16i					
		16ii					
	Total Phase 2						
3		16i					
		16ii					
	Total Phase 3						
n		16i					
		16ii					
	Total Phase n						

Replacement Schedule	
Year	Cost

iv. Project Present-Worth cost.

Interest _____%

Present-Worth Cost $_____

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

Notes on Methodology Logic

Step 1 (Item 1) - This step of the evaluation will indicate if there might be a monetary cost advantage for the use of an environmental modification with the selected control alternatives. This will be indicated by the nature of the control objective as indicated by the desired versus actual water quality condition. This decision can be aided by determining whether the source load-reduction identified for the strategy and for the source under consideration is determined by the water quality standards of the receiving water (Water Quality Limited) or treatment standards (Effluent Limited). If the segment is Water Quality Limited, then modifying the impact of the discharge is more likely to favorably alter the physical characteristic of the receiving water.

Step 2 (Item 2) - The relocation of the source load discharge point might be feasible if another stream or other body of water near the discharge site has less stringent water quality criteria than the proposed receiving water, or if another location on the existing receiving water has a greater assimilative capacity than the existing discharge site, etc., as described by general conditions in this item. The user should note that unless there is a reduced cost associated with treatment, the cost of transporting the treated source effluent to the new discharge site will make discharge relocation an unattractive monetary cost alternative.

Step 2a, b, c (Items 3, 4) - The required level of treatment at the alternate site should be evaluated utilizing the impact analysis in Chapter 5. If this level of treatment is confirmed to be less than that required for discharge at the existing site, then the costs associated with transportation and the lower treatment level should be evaluated. A regionalized discharge also could be considered.

Step 2d, e, f, g, h (Items 5, 6, 7) - The monetary cost associated with discharge relocation for each identified alternative site is evaluated using the appropriate methodologies.

Step 3a (Item 8) - Artificial stream reaeration will be a feasible alternative when the water quality parameter of concern is the minimum D.O. of the receiving water. This information should be available from earlier determinations (Item 1).

Step 3b (Item 9) - Where the receiving water D.O. is the critical water quality parameter, it will be necessary to run the water quality impact analysis in Chapter 5 using an increased wastewater source load to the receiving water to define the effect on stream D.O. (Item 9). The D.O. deficit of the receiving water should therefore be defined using this modified load.

Step 3c (Item 10) - The monetary cost associated with artificial reaeration of the receiving water is determined in Item 10. First, the oxygen deficit at the critical point in the receiving water is calculated on the basis of the stream flow rate at the model conditions, the minimum (critical) D.O. concentration at the critical point, and the desired D.O. level at that point. The required oxygen transfer can therefore be defined. In addition, the estimated time that reaeration will be required should also be estimated. The cost for artificial reaeration can then be computed utilizing site-specific information.

Step 3d, e (Items 11, 12) - The treatment cost for the modified level of treatment associated with the artificial reaeration evaluation should be computed using the TREATMENT FACILITY METHODOLOGY. The Present-Worth cost of the artificial reaeration alternative can then be evaluated using the PRESENT-WORTH METHODOLOGY.

Step 4a (Item 13) - This step is used to determine if augmentation of the receiving water flow might be feasible as an alternative to the proposed level of treatment for the source. That is, if the source load level of treatment is defined by the low-flow condition of the receiving water, then it might be feasible to increase the allowable load of the critical parameters by increasing the flow rate of the receiving water. Therefore, the first condition that must be satisfied is that the critical parameter in the allowable level of discharge is determined by the low-flow condition of the receiving water (Item 4). This information should be available from the water quality impact analysis of Chapter 5.

Step 4b, (Item 14) - Where flow augmentation could reduce the level of treatment, the existing capability for low-flow augmentation must be identified. This evaluation will require information on the available water supply upstream of the source discharge that can be used for low-flow augmentation.

The assigned capacity for low-flow augmentation or the potential capacity for this use should be identified as to the available rate of discharge and also the length of time that this discharge can be maintained.

Step 4c (Item 15) - The low-flow rate in the receiving water should be modified to consider the flow available from the identified water supplies, and the water quality impact analysis should be used to calculate the revised level of treatment identified for the critical parameters.

Step 4d, e, f (Items 15, 16) - A revised treatment cost for this identified level of treatment is developed using the appropriate methodology. The Present-Worth cost of flow-augmentation alternatives can then be evaluated by considering the monetary costs associated with utilizing the flow augmentation capacity of the identified water supply and the treatment cost associated with the reduced level of treatment.

The scope of this evaluation does not include consideration of the alternative of creating a water supply, especially for low-flow augmentation for a specific wastewater source of interest. This alternative, however, could be feasible in a specific case. For example, a situation where the natural topography would lend itself to the creation of a reservoir might be a situation where a low-flow augmentation water supply could be readily developed.

6.4.2.10 Regionalization Methodology

Discussion

The purpose of the REGIONALIZATION METHODOLOGY is to identify situations where the monetary cost associated with a control alternative can be reduced by handling two or more waste discharges at a common site. This methodology will direct the user in evaluating regionalization of several wastewater treatment facilities, as well as the utilization of a common disposal site for several residual generators. However, the residuals disposal portion of this methodology is independent of the treatment portion; therefore, it can and should be used independently.

The REGIONALIZATION METHODOLOGY guides the user in identifying feasible regionalization combinations for wastewater treatment, and then determining the cost associated with these combinations. Although generally applicable to municipal point sources, regionalization may include joint municipal-industrial or cooperative-industrial treatment facilities. In the latter case, the user would not estimate costs, but would be interested in effects upon wasteload allocations and water quality.

Following the analysis of the wastewater source combinations, the user evaluates the development of a regional residual disposal facility. This sequence of steps (wastewater regionalization, residuals disposal combination) is recommended since the residuals generated by a regional plant might differ from those generated by the initially-identified, point-source control alternatives.

Utilization of the REGIONALIZATION METHODOLOGY will be most effective when the user is aware of the factors in the specific planning area that would make a combination of several sources into one facility desirable. In most cases, these will be both positive and negative effects from regionalization which the user should consider. Typically, the greatest advantage of a regional facility versus several smaller facilities is the economy of scale associated with constructing, operating, and managing one large facility rather than several smaller ones. Larger and more efficient operating budgets, and efficient distribution and use of personnel are also benefits of concentrating facilities and responsibilities for wastewater management.

In some cases, however, savings in treatment plant construction may be offset by increased collection system and operations and maintenance costs. In evaluating regionalization alternatives, the user should also consider the following potential effects:

1. Potential higher concentration of pollutants.
2. More pronounced consequences of treatment plant failures.
3. More sophisticated treatment plant which may be beyond local operating capabilities.
4. Inducement of urban growth along interceptor sewers.

Although many of the concerns are not specifically addressed in the REGIONALIZATION METHODOLOGY, the user is encouraged to assess these effects in a broader evaluation framework.

Perhaps the most important step in this REGIONALIZATION METHODOLOGY is the identification of potential regional sites. It is not the intent of this manual to limit the user to identifying existing plants or disposal sites as the only potential regional sites. Any tract of land that would be suitable for a large wastewater treatment facility or disposal site should be evaluated.

The treatment facilities (referred to as satellite facilities) that are combined with the proposed regional site are important to the effective use of the REGIONALIZATION METHODLOGY. Typically, the user would want to identify combinations of regional and satellite facilities with higher individual costs, since these combinations would have the greatest impact on the overall alternative cost. However, the user should not limit his evaluation only to the larger wastewater sources.

A decision step is included in this methodology relative to the identification of additional regional/satellite combinations. This is included after each combination has been evaluated to insure: first, that the user will not have to identify every potential regional/satellite combination before determining the impact of these source combinations; and, secondly, to be certain that the evaluation of regionalization continues until the reasonable combinations have been evaluated. This decision step will require good judgment

by the user who should utilize the trends apparent from the use of the previous methodologies to evaluate the potential benefit from further combinations. The user should continue these evaluations until the cost savings cease.

In certain cases, even with demonstrable economies, regionalization may not be locally acceptable. Therefore, as part of the evaluation process, the user should be aware of attitudes concerning regionalization.

Methodology Logic

A summary of the logic of the REGIONALIZATION METHODOLOGY is presented in Figure 6-25. An exapnded flowchart, Figure 6-26, lists the steps to be taken in determining performance and costs. The worksheet for recording the operations is presented as Table 6-15. Notes on specific steps or worksheet items are presented following the worksheets.

FIGURE 6-25

REGIONALIZATION METHODOLOGY
LOGIC SUMMARY

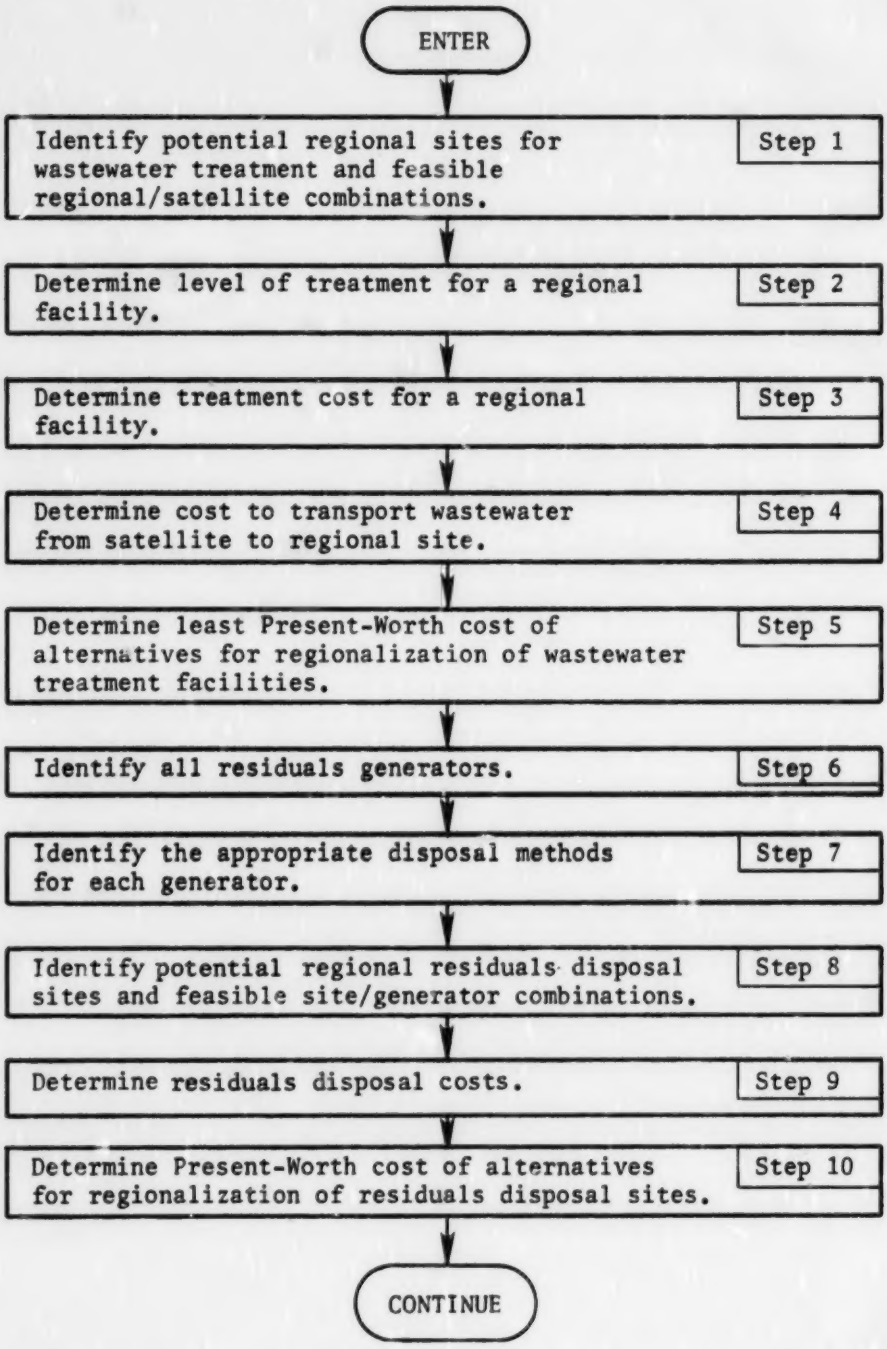
ENTER
Identify potential regional sites for wastewater treatment and feasible regional/satellite combinations.
Step 1
Determine level of treatment for a regional facility.
Step 2
Determine treatment cost for a regional facility.
Step 3
Determine cost to transport wastewater from satellite to regional site.
Step 4
Determine least Present-Worth cost of alternatives for regionalization of wastewater treatment facilities.
Step 5
Identify all residuals generators.
Step 6
Identify the appropriate disposal methods for each generator.
Step 7
Identify potential regional residuals disposal sites and feasible site/generator combinations.
Step 8
Determine residuals disposal costs.
Step 9
Determine Present-Worth cost of alternatives for regionalization of residuals disposal sites.
Step 10
CONTINUE

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FIGURE 6-26

REGIONALIZATION METHODOLOGY
FLOWCHART

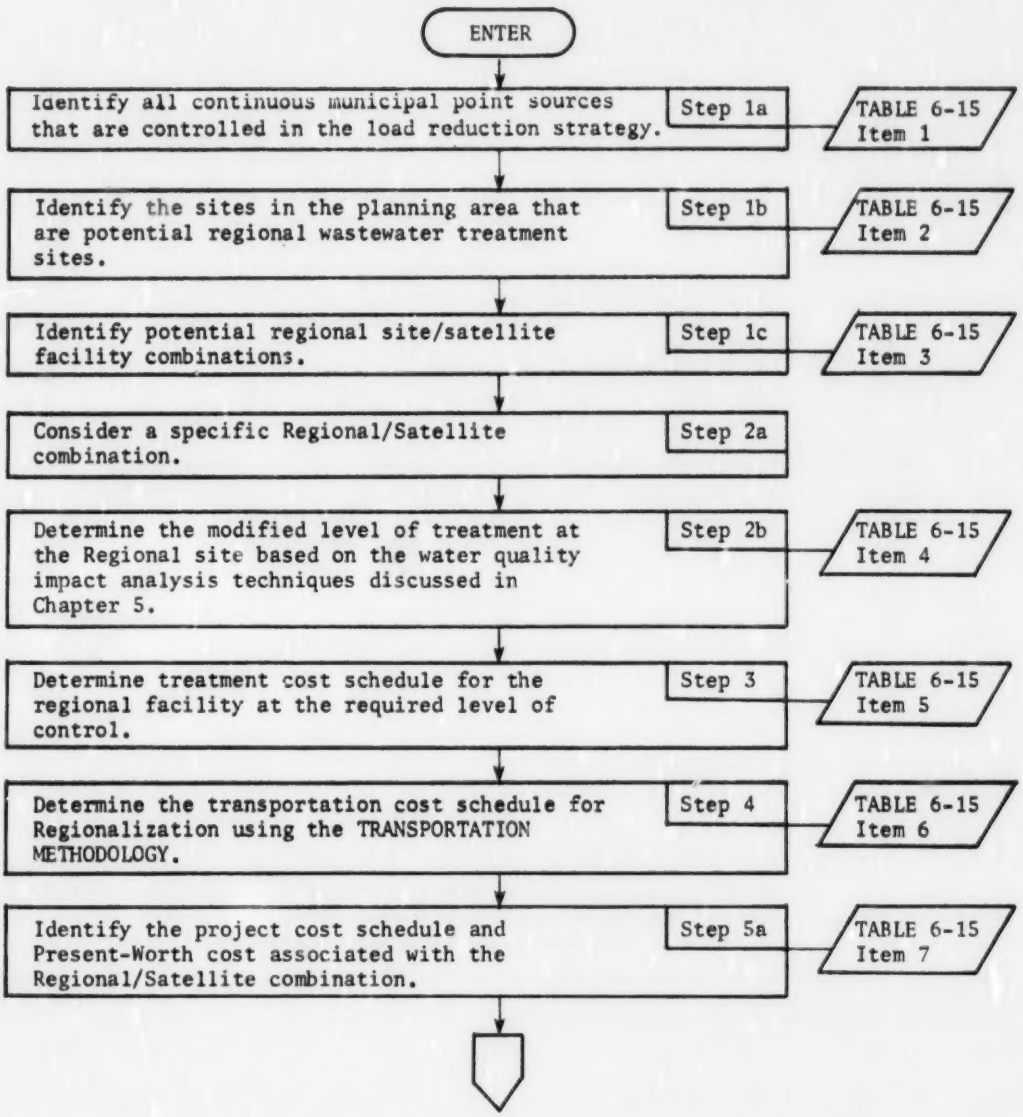
ENTER
Identify all continuous municipal point sources that are controlled in the load reduction strategy.
Step 1a
TABLE 6-15 Item 1
Identify the sites in the planning area that are potential regional wastewater treatment sites.
Step 1b
TABLE 6-15 Item 2
Identify potential regional site/satellite facility combinations.
Step 1c
TABLE 6-15 Item 3
Consider a specific Regional/Satellite combination.
Step 2a
Determine the modified level of treatment at the Regional site based on the water quality impact analysis techniques discussed in Chapter 5.
Step 2b
TABLE 6-15 Item 4
Determine treatment cost schedule for the regional facility at the required level of control.
Step 3
TABLE 6-15 Item 5
Determine the transportation cost schedule for Regionalization using the TRANSPORTATION METHODOLOGY.
Step 4
TABLE 6-15 Item 6
Identify the project cost schedule and Present-Worth cost associated with the Regional/Satellite combination.
Step 5a
TABLE 6-15 Item 7

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FIGURE 6-26 (CONTINUED)

REGIONALIZATION METHODOLOGY
FLOWCHART

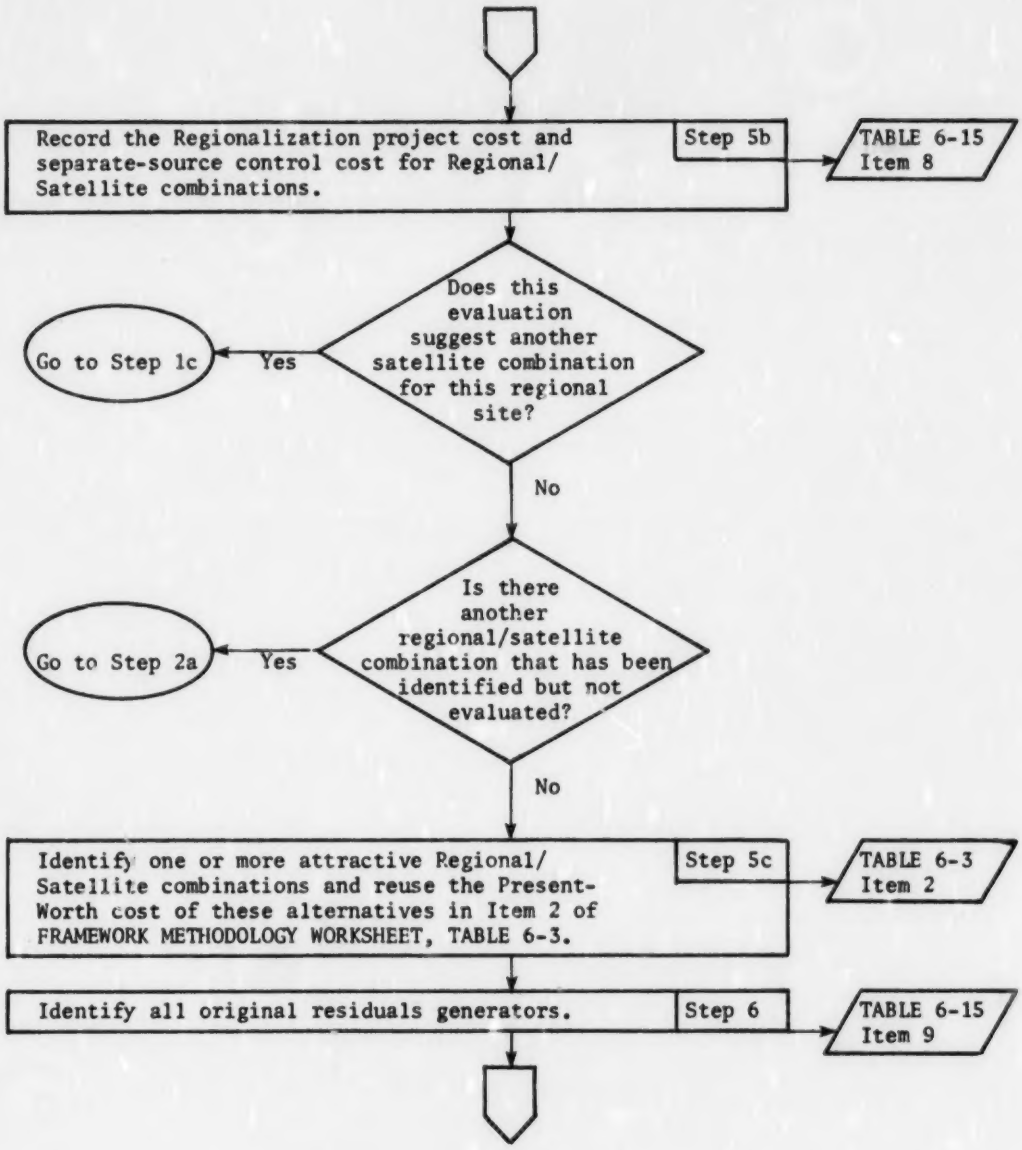
Record the Regionalization project cost and separate-source control cost for Regional/ Satellite combinations.
Step 5b
TABLE 6-15 Item 8
Does this evaluation suggest another satellite combination for this regional site?
Yes
Go to Step 1c
No
Is there another regional/satellite combination that has been identified but not evaluated?
Yes
Go to Step 2a
No
Identify one or more attractive Regional/ Satellite combinations and reuse the Present-Worth cost of these alternatives in Item 2 of FRAMEWORK METHODOLOGY WORKSHEET, TABLE 6-3.
Step 5c
TABLE 6-3 Item 2
Identify all original residuals generators.
Step 6
TABLE 6-15 Item 9

FIGURE 6-26 (CONTINUED)

REGIONALIZATION METHODOLOGY
FLOWCHART

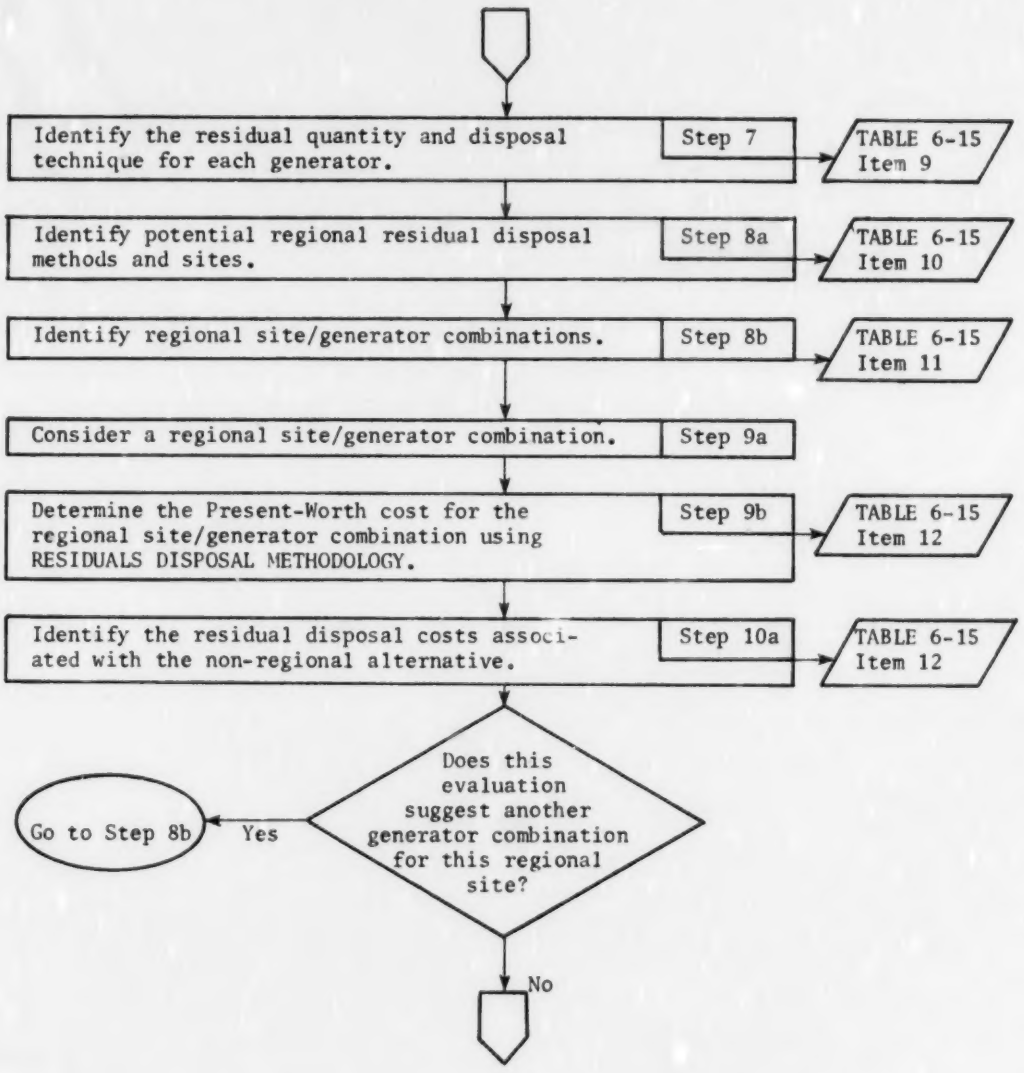
Identify the residual quantity and disposal technique for each generator.
Step 7
TABLE 6-15 Item 9
Identify potential regional residual disposal methods and sites.
Step 8a
TABLE 6-15 Item 10
Identify regional site/generator combinations.
Step 8b
TABLE 6-15 Item 11
Consider a regional site/generator combination.
Step 9a
Determine the Present-Worth cost for the regional site/generator combination using RESIDUALS DISPOSAL METHODOLOGY.
Step 9b
TABLE 6-15 Item 12
Identify the residual disposal costs associated with the non-regional alternative.
Step 10a
TABLE 6-15 Item 12
Does this evaluation suggest another generator combination for this regional site?
Yes
Go to Step 8b
No

FIGURE 6-26 (CONTINUED)

REGIONALIZATION METHODOLOGY
FLOWCHART

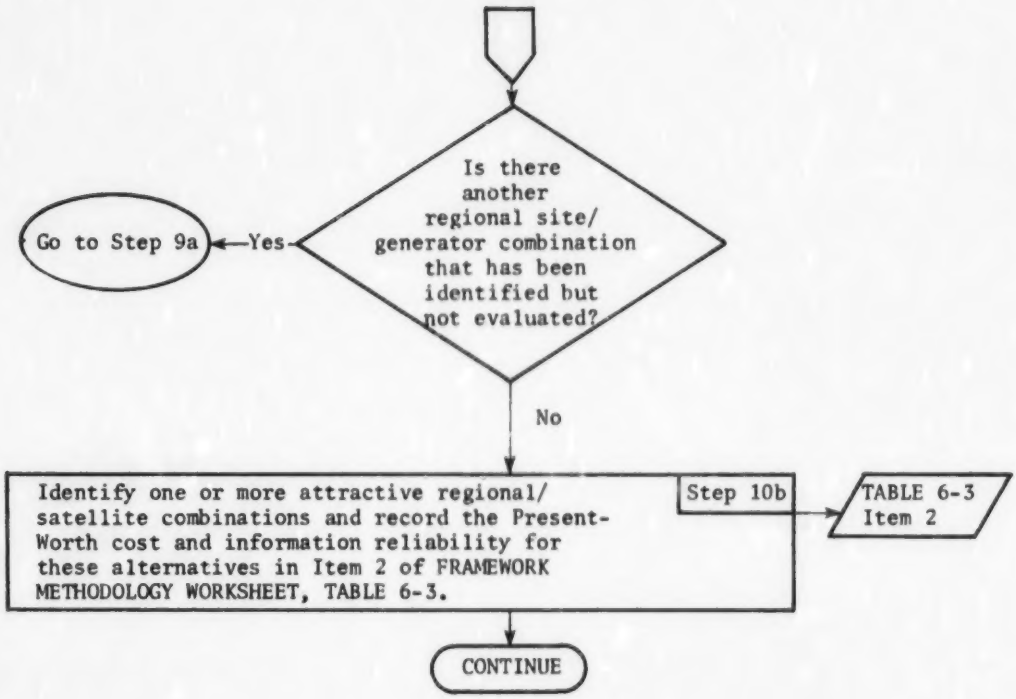
Is there another regional site/ generator combination that has been identified but not evaluated?
Yes
Go to Step 9a
No
Identify one or more attractive regional/ satellite combinations and record the Present-Worth cost and information reliability for these alternatives in Item 2 of FRAMEWORK METHODOLOGY WORKSHEET, TABLE 6-3.
Step 10b
TABLE 6-3 Item 2
CONTINUE

TABLE 6-15
REGIONALIZATION METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgments presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach available (or even as the preferred approach). However, any approach used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other EPA, State, and local guidelines and regulations.

Wastewater Treatment Regional Site Evaluation

Item 1 - Source Identification.
(Attach topographic map with sources located)

	Source/Location	Flow	Level of Control/ Critical Parameters
a)			
b)			
c)			
d)			
e)			
f)			
g)			
h)			
i)			
j)			
k)			
l)			
m)			
n)			

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TABLE 6-15 (continued)
REGIONALIZATION METHODOLOGY
WORKSHEET

Item 2 - Regional Site Identification.
(Attach topographic map with sources located)

	Site/Location	Available Area (acres)	Estimated Max. Flow (mgd)	Existing Condition
a)				
b)				
c)				
d)				
e)				
f)				
g)				
h)				
i)				
j)				
k)				
l)				
m)				
n)				

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TABLE 6-15 (continued)
REGIONALIZATION METHODOLOGY
WORKSHEET

Item 3 - Potential Regional Site/Source Combinations.

Combination I.D. No.	Source 1		Source 2		Regional Site		
	I.D.	Q (mgd)	I.D.	Q (mgd)	I.D.	Max Site Q (mgd)	Max Design Q (mgd)
1							
2							
3							

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TABLE 6-15 (continued)
REGIONALIZATION METHODOLOGY
WORKSHEET

REGIONAL SITE EVALUATION

Regional Combination No. _____

Item 4 - Level of Treatment at Regionalization Site.

	Parameter	Raw Wastewater	Discharge Level	Level of Treatment
a)				
b)				
c)				

Level of Treatment:

Item 5 - Regional Site Wastewater Treatment Cost Schedule.
(Use the TREATMENT FACILITY METHODOLOGY)

Phase	Timing Yr.	to Yr.	Capital	O&M Start	O&M End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Existing Facility								
1								
2								
3								
n								

Item 6 - Wastewater Transportation Cost Schedule.
(Use the TRANSPORTATION COST METHODOLOGY)

Phase	Timing Yr.	to Yr.	Capital	O&M Start	O&M End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Existing Facility								
1								
2								
3								
n								

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TABLE 6-15 (continued)
REGIONALIZATION METHODOLOGY
WORKSHEET

Item 7 - Regionalization Cost Evaluation.

i. Cost Schedule (Regional Combination No. _____)

Phase	Timing Yr to Yr	Item	Capital Cost	Start O&M	End O&M	Variable O&M	Salvage Value
1		# 5					
		# 6					
			____	____	___	____	____
TOTAL PHASE 1							
2		# 5					
		# 6					
			____	____	___	____	____
TOTAL PHASE 2							
3		# 5					
		# 6					
			____	____	___	____	____
TOTAL PHASE 3							
4		# 5					
		# 6					
			____	____	___	____	____
TOTAL PHASE 4							

Replacement Schedule

Item	Year	Cost
___	___	___
___	___	___

ii. Present-Worth Project Cost: $_____

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TABLE 6-15 (continued)
REGIONALIZATION METHODOLOGY
WORKSHEET

Item 8 - Present-Worth Cost.

Regional Site I.D.	Source I.D. No. 1	Source I.D. No. 2	Separate Treatment Costs Source 1	Separate Treatment Costs Source 2	Regional Treatment Cost

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TABLE 6-15 (continued)
REGIONALIZATION METHODOLOGY
WORKSHEET

Residuals Disposal Regional Site Evaluation

Item 9 - Residuals Generator Source Identification.

Source/Location	Flow (mgd)	Residual Disposal Method	Residual Characteristics Quality	Type
a)				
b)				
c)				
d)				
e)				
f)				
g)				
h)				
i)				
j)				
k)				
l)				
m)				
n)				

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TABLE 6-15 (continued)
REGIONALIZATION METHODOLOGY
WORKSHEET

Item 10 - Potential Residual Disposal Sites.

	Site/Location	Available Area (acres)	Estimated Capacity	Existing Condition
a)				
b)				
c)				
d)				
e)				
f)				
g)				
h)				
i)				
j)				
k)				
l)				
m)				
n)				

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TABLE 6-15 (continued)
REGIONALIZATION METHODOLOGY
WORKSHEET

Item 11 - Potential Regional Site/Generator Combinations.

	Regional Site		Generator		
	Site I.D.	Capacity	I.D.	Location	Quantity
a.					
b.					

Item 12 - Regional Site/Generator Combined Present Worth Costs.
(Using the RESIDUALS DISPOSAL METHODOLOGY)

	Combination Generator I.D.	Present Worth Cost at Combination	Present Worth Cost Separate
a.			
		TOTAL	
b.			
		TOTAL	

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Remarks: _____ Page _____

Notes on Methodology Logic

Step 1a (Item 1) - The purpose of this step is to identify the wastewater sources that are controlled in the strategy under consideration. The information developed in this step should be useful in identifying the desired source combinations for the separate regional facilitiy evaluations.

Step 1b (Item 2) - The potential regional sites are identified in this step. There are numerous factors that will indicate a potential regional site in the particular planning area. For the general condition, any existing wastewater treatment site is a potential regional site, especially if there is adequate room for expansion. However, it is not the intent to limit potential regional sites to existing facilities; the user should attempt to identify any suitable location in the planning area that satisfies the basic requirements for a wastewater treatment facility. References should be consulted for more information concerning facilities siting. For example, a large undeveloped area lying in the proximity of several small treatment sites might be identified as a potential regional site if it were at a lower elevation than these sites. The information identified for the potential regional sites should be recorded on the worksheet (Item 2) and should include: the location of the site, the available area, the estimated maximum treatment capacity (flow), and the existing condition of the site (e.g., existing structures, utilities, roads, vegetation, etc.).

Step 1c (Item 3) - In identifying the source combinations for further study, the proposed regional site is designated as the regional site, and the source or sources that are to be relocated to the regional site are identified as satellite sources. The worksheet is designed to evaluate two wastewater sources combined at a regional treatment site, where the regional site can be considered as one of the existing sources when desired. The user can evaluate more complex situations by an iterative procedure utilizing these worksheets and by considering a regional site combination as one of the sources. There is an opportunity later in the methodology to identify additional regional/satellite combinations based on the results of the evaluation.

Step 2a - This step selects one of the combinations identified in Step 1c (Item 3) for a detailed monetary cost evaluation.

Step 2b (Item 4) - The water quality impact analysis techniques in Chapter 5 used to define the level of treatment required for each source must be modified to reflect the exclusion of the loads from the sources that have been relocated to the regional site. The level of treatment required at the regional site is then identified to maintain an acceptable water quality for the receiving stream. When regionalization does not cause a significant change in the pollutant loading pattern to the receiving body, the control level for the regional facilities will be the same as that required at the separate sources.

Step 3 (Item 5) - This step identifies the treatment cost schedule for the regional facility. Several alternative treatment methods can be evaluated as desired using the TREATMENT FACILITY and LAND APPLICATION METHODOLOGIES. The worksheet is designed to present a summary of the selected treatment system cost schedule.

Step 4 (Item 6) - This step identifies the wastewater transportation cost schedule for the regionalization project. This can be developed using the TRANSPORTATION COST METHODOLOGY and summarized in the Regionalization Worksheet.

Step 5a (Item 7) - This step presents the total project cost schedule. This will include treatment costs (Item 5), transportation costs (Item 6), and other special costs identified for the project. The PRESENT-WORTH METHODOLOGY is used in this step to develop the Project Present-Worth cost.

Step 5b (Item 8) - This step summarizes the costs developed for the various regionalization evaluations. The user can utilize Item 8 in identifying control alternatives for further (non-monetary cost) evaluation. Following the summarization of a regional cost, the user should determine if another combination is suggested. This might involve the combination of two previously identified regional facilities into another larger regional facility. This can be accomplished in Step 1c by identifying these regional facilities as the satellite sites.

Step 6 (Item 9) - The purpose of this step is to inventory the residual generators in the planning area. This identification should also include the residuals generated in the wastewater regionalization evaluation. The

characteristics of each residual should include the nature of the sludge (biological or chemical) and the condition of the sludge (wet, cake, or ash) as identified in the treatment system cost curves, as well as the general area and disposal options available.

Step 7 (Item 9) - The purpose of this step is to identify the proposed disposal methods for each of the residual generators as either land spreading or landfilling. The usefulness of this inventory will be in later identifying potential combinations for a specific regional disposal site. The quantity of residuals from each generator should also be identified in this step.

Step 8a (Item 10) - In this step the potential regional residual disposal sites are identified. This list, of course, should include all sites identified for the disposal of the individual point-source residuals. However, this list should also include future sites that could be developed for a regional residual disposal site; this is particularly important in evaluating the regionalization of residual disposal sites since the capacity at the existing sites might limit regionalization potential. The characteristic of the potential residual disposal sites should specifically address any condition at the site that would enhance or limit its applicability for residual disposal.

Step 8b (Item 11) - In this step the potential regional site/residual generator combinations are identified. In the first analysis of regionalization, the user should identify the combinations that would have the most significant impact on the monetary costs of the control strategy; typically, this would indicate the larger quantities of residuals and those residuals with a significant disposal cost. In addition, the user may wish to consider a combination of a potential regional site with several residual generators. This would allow the user to identify a common disposal site cost and the individual residual transportation cost in one analysis, thereby saving computational effort. The user should rely upon the experience obtained in performing the individual residual disposal evaluations to identify these combinations, as well as any local situation that would impact on a regional residual disposal site.

Step 9a - In this step the user selects a residual disposal combination for the Present-Worth evaluation.

Step 9b (Item 12) - The Present Worth cost for the regional disposal site/generator combination is evaluated in this step. This cost is developed using the Residual Disposal Methodology and the combined residual characteristics. The costs associated with the regional disposal site include the site cost and the transportation cost for each residual to the site.

Step 10a (Item 12) - This step identifies the residual disposal costs determined when the separate disposal evaluations were performed. The regional disposal cost can then be compared to the separate disposal cost to identify relative monetary costs. This might suggest further residual combinations for evaluation.

Step 10b - In this step the user identifies the least Present-Worth cost residual disposal technique from the information summarized in Item 12.

6.4.2.11 Present-Worth Methodology

Discussion

The purpose of this methodology is to determine the Present-Worth cost of an alternative. The worksheet is designed to evaluate project cost schedules developed by the evaluation procedures for each control alternative; it can handle projects with up to four construction phases, but could readily be modified to include more. The costs identified in the worksheet include construction cost, constant and variable operation and maintenance (O & M) costs, existing facility phase out costs, facility replacement costs, and facility salvage value. This procedure converts these costs over the project life into an equivalent cost that represents the current investment that would be required to satisfy all of the identified project costs for the planning period. For a more detailed discussion, the user may consult any standard engineering economy text, including reference(20).

The construction costs incurred by the project represent single-payment costs that occur at certain times throughout the planning period. The single-payment present-worth factor (sppwf) is used to determine the Present-Worth cost, and is determined by the following formula:

$$sppwf = \frac{1}{(1 + i)^n} \qquad (6\text{-}1)$$

where:

i is the interest
n is the number of interest periods

The operation and maintenance (O & M) cost includes both constant and variable costs. The constant O & M cost is based on the flow rate at the beginning of the planning period. The variable O & M cost represents the difference between the O & M cost at the flow rate in the final year of the planning period and the constant O & M cost identified by the flow rate at the beginning of the planning period.

The uniform-series present-worth factor (uspwf) is used to convert the constant annual O & M cost to a Present-Worth cost by the formula:

$$uspwf = \frac{(1 + i)^n - 1}{i\ (1 + i)^n} \qquad (6\text{-}2)$$

where:

i is the interest rate
n is the number of interest periods

For cases where the constant payment is for a period that does not start at the beginning of the planning period (Phase 2 constant O & M costs), the uniform-series factor must be adjusted by multiplying it by the single-payment present-worth factor for the number of years from the beginning of the planning period to the time that the constant payment begins, as in the following:

$$(uspwf^{t1}) \times (sppwf^{t2}) \qquad (6\text{-}3)$$

where:

t1 is the number of years that the constant payment will be made

t2 is the number of years from the beginning of the planning period to the time that the constant payment begins

The variable operation and maintenance costs are assumed to vary linearly through the planning period and are multiplied by the gradient-series present-worth factor for the same number of years that the corresponding constant operation and maintenance is paid ($gspwf^a$-years). This value is computed as:

$$gspwf = \frac{\left[\frac{(1 + i)^n - 1}{i\ (1 + i)^n}\right] - n\left[\frac{1}{(1 + i)^n}\right]}{(i)} \qquad (6\text{-}4)$$

where:

i is the interest rate
n is the number of interest periods that the series is in effect

When using this term for computing the Present-Worth of a variable O & M cost, care must be exercised to insure that the gradient O & M is used (i.e., the annual average increase in O & M costs during the phase.

If the gradient series does not start at the beginning of the planning period, it must be adjusted by multiplying it by the single-payment present-worth factor as follows:

$$(gspwf^{t1}) \times (sppwf^{t2}) \qquad (6\text{-}5)$$

where:

t1 is the period in which the gradient series is in effect

t2 is the number of years from the beginning of the planning period to the time the variable payment is started

In practice, the user will find it more convenient to consult appropriate tables in an engineering economy text; if tables are not available, the preceding formulas will provide comparable results.

The facility replacement cost identifies the cost required to extend the useful life of equipment to the end of the planning period. This is computed when a cpaital item has a service life less than the remaining years in the planning period, and is computed by:

$$\text{Replacement Cost} = \frac{\text{Planning Period - Remaining Service Life}}{\text{Service Life}} \times \text{Capital Value} \qquad (6\text{-}6)$$

where Capital Value represents the capital that would be required today to completely replace the facility. This is a single-payment cost, with Present Worth computed using the factor sppwf.

Finally, the salvage valve represents the value remaining for all capital at the end of the planning period, and is computed by:

$$\text{Salvage Value} = \frac{\text{Service Life - Years to Planning End}}{\text{Service Life}} \times \text{Capital} \qquad (6\text{-}7)$$

where Capital (or Capital Value) represents the initial investment (or cost to replace today). This is a negative cost, with the Present-Worth value computed using the factor sppwf.

Methodology Logic

A summary of the logic of the Present-Worth Methodology is presented in Figure 6-27. An expanded flowchart, Figure 6-28, lists the steps to be taken in determining performance and costs. The worksheet for recording the operations is presented as Table 6-16. Notes on specific steps or worksheet items are presented following the worksheets.

FIGURE 6-27

PRESENT-WORTH METHODOLOGY
LOGIC SUMMARY

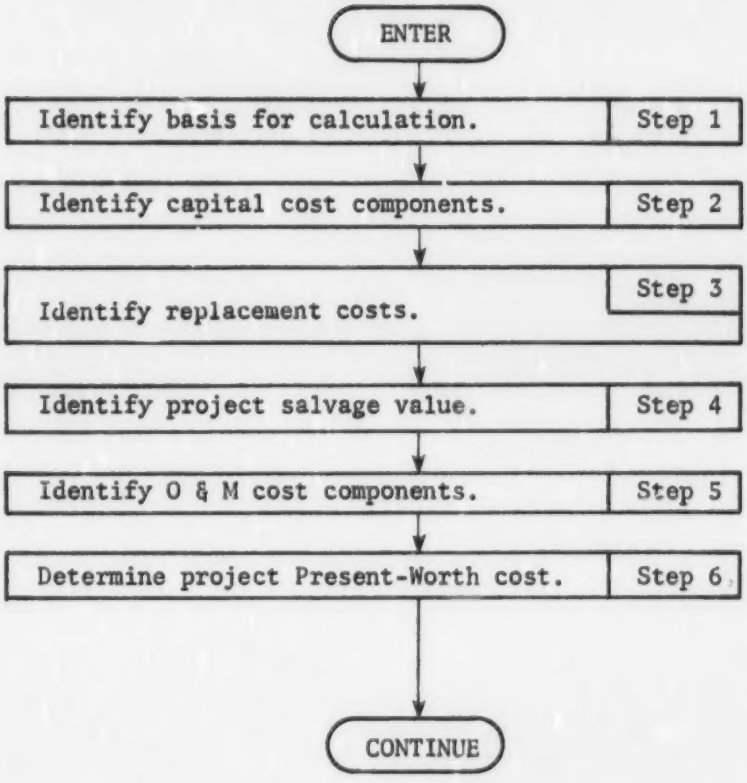

FIGURE 6-28

PRESENT-WORTH METHODOLOGY
FLOWCHART

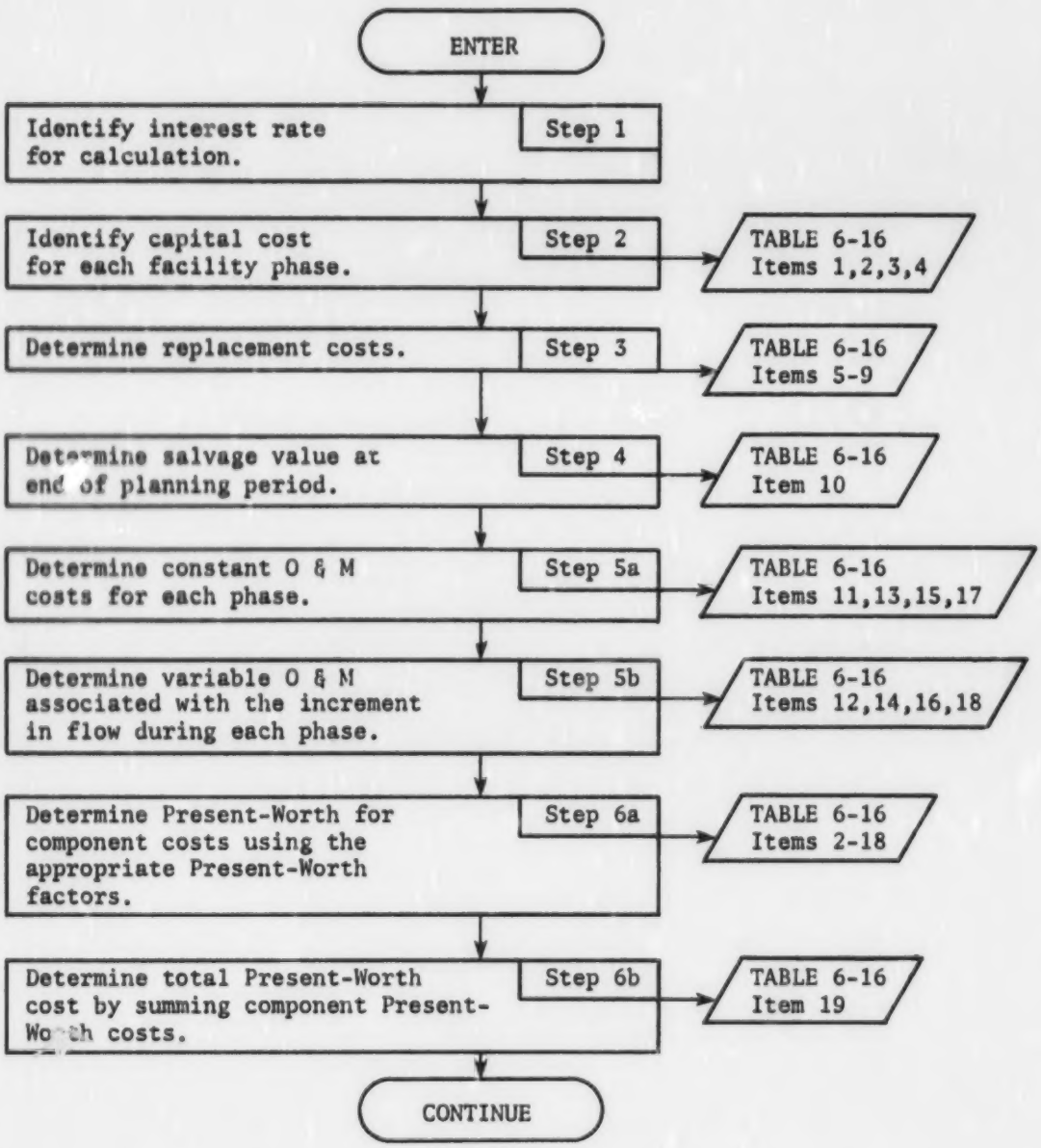
ENTER
Identify interest rate for calculation.
Step 1
Identify capital cost for each facility phase.
Step 2
TABLE 6-16 Items 1,2,3,4
Determine replacement costs.
Step 3
TABLE 6-16 Items 5-9
Determine salvage value at end of planning period.
Step 4
TABLE 6-16 Item 10
Determine constant O & M costs for each phase.
Step 5a
TABLE 6-16 Items 11,13,15,17
Determine variable O & M associated with the increment in flow during each phase.
Step 5b
TABLE 6-16 Items 12,14,16,18
Determine Present-Worth for component costs using the appropriate Present-Worth factors.
Step 6a
TABLE 6-16 Items 2-18
Determine total Present-Worth cost by summing component Present-Worth costs.
Step 6b
TABLE 6-16 Item 19
CONTINUE

TABLE 6-16
PRESENT-WORTH METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgements presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach-available (or even as the preferred approach). However, any approaches used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other EPA, State, and local guidelines and regulations.

Items 1-10 Present-Worth Calculation.

Planning Period 20 years Interest _____%

	Item (Reference Page)	Amount		Present-Worth
1.	Phase 1 Capital (pg. ___)	_____ x	1.0 (Yr 1)	_____
2.	Phase 2 Capital (pg. ___)	_____ x	_____ ($sppwf^a$) (Yr ___)	_____
3.	Phase 3 Capital (pg. ___)	_____ x	_____ ($sppwf^b$) (Yr ___)	_____
4.	Phase n Capital (pg. ___)	_____ x	_____ ($sppwf^c$) (Yr ___)	_____
5.	Replacement year (h) (pg. ___)	_____ x	_____ ($sppwf^h$) (Yr ___)	_____
6.	Replacement year (i) (pg. ___)	_____ x	_____ ($sppwf^i$) (Yr ___)	_____
7.	Replacement year (j) (pg. ___)	_____ x	_____ ($sppwf^j$) (Yr ___)	_____
8.	Replacement year (k) (pg. ___)	_____ x	_____ ($sppwf^k$) (Yr ___)	_____
9.	Replacement year (l) (pg. ___)	_____ x	_____ ($sppwf^l$) (Yr ___)	_____
10.	Salvage Value (Negative Cost) (pg. ___)	_____ x	_____ ($sppwf^z$) (Yr ___)	_____

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Remarks: _____ Page _____

TABLE 6-16 (continued)
PRESENT-WORTH METHODOLOGY
WORKSHEET

Item 11 - 19 Present-Worth Calculation.

Planning Period 20 years Interest _____%

	Item (Reference Page)	Amount		Present-Worth
11.	O&M Phase 1 Constant (pg. ___)	_____	x ____($uspwf^d$) x 1.0 (#Yrs____;Yr 1)	_____
12.	O&M Phase 1 Variable (pg. ___)	_____	x ____($gspwf^d$) x 1.0 (#Yrs____;Yr 1)	_____
13.	O&M Phase 2 Constant (pg. ___)	_____	x ____($uspwf^e$ x $sppwf^a$) (#Yrs____;Yr____)	_____
14.	O&M Phase 2 Variable (pg. ___)	_____	x ____($gspwf^e$ x $sppwf^a$) (#Yrs____;Yr____)	_____
15.	O&M Phase 3 Constant (pg. ___)	_____	x ____($uspwf^f$ x $sppwf^b$) (#Yrs____;Yr____)	_____
16.	O&M Phase 3 Variable (pg. ___)	_____	x ____($gspwf^f$ x $sppwf^b$) (#Yrs____;Yr____)	_____
17.	O&M Phase n Constant (pg.___)	_____	x ____($uspwf^g$ x $sppwf^c$) (#Yrs____;Yr____)	_____
18.	O&M Phase n Variable (pg.___)	_____	x ____($gspwf^g$ x $sppwf^c$) (#Yrs____;Yr____)	_____
19.			TOTAL PRESENT-WORTH	$_____

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

Notes on Methodology Logic

Step 1 - The rate of interest should be selected to realistically reflect the prevailing interest rates and inflationary trends. The actual interest rate which must be used is published annually by the U.S. Water Resources Council 18 CFR 704.39, Discount Rate, Federal Register published annually. The interest rate selected should be the same for each alternative.

Step 2 (Items 1, 2, 3, 4) - The capital cost for each phase will be available from the project cost schedule. The timing for each capital investment and all other costs should be recorded on the worksheet in (Yr____), with the page number of the calculation recorded in (pg. ____). The superscripts (a, b, c, etc.) are for reference purposes to aid in identifying the factors that are identical.

Step 3 (Items 5, 6, 7, 8, 9) - The replacement cost schedule will be available from the project cost schedule.

Step 4 (Item 10) - The project salvage value for all capital expenditure will be available from the project cost schedule, and represents a negative cost at the end of the period.

Step 5a (Items 11, 13, 15, 17) - The constant O & M costs will be available from the project cost schedule.

Step 5b (Items 12, 14, 16, 18) - The variable O & M costs will be available from the project cost schedule or can be computed using:

$$\text{Variable O \& M}_{\text{(Phase 1)}} = \frac{\text{Constant O \& M (Phase 2)} - \text{Constant O \& M (Phase I)}}{\text{Years in Phase 1}}$$

Step 6a (Items 2 to 18) - The required Present-Worth factors will generally be available from standard tables. If the required interest rate is not identified in the tables, these factors can be computed using the formulas described in the general discussion section.

Step 6b (Item 19) - The Present-Worth is determined by adding the separate Present-Worth costs and subtracting the Present-Worth of the salvage value.

6.4.2.12 Residuals Disposal Methodology

Discussion

The purpose of this methodology is to identify costs associated with disposing of the residuals generated by a wastewater treatment process. The TREATMENT FACILITY METHODOLOGY identifies residual handling and treatment costs as well as the wastewater treatment costs; therefore, this methodology will identify only the costs associated with transporting the treated residuals to the disposal site and with disposing of the residuals at the site.

This methodology includes two ultimate disposal alternatives for wastewater treatment residues: land spreading or landfilling. These disposal techniques are similar in their transportation requirements and are the most widely used techniques at this time. However, there is no intent to limit the user to evaluation of these alternatives only. For discussion of other residuals handling techniques, the user should consult references(21-24). There may be opportunities for cost-effective disposal of wastes that would apply only to a specific locality, such as an abandoned mine. The user is encouraged to seek a local solution to his disposal problem. Even if the alternatives other than the two suggested above are considered, parts of this methodology can serve as guidance in determining costs. Evaluation of residuals disposal practices must include consideration of local attitudes, potential socio-economic effects, and public health implications.

Methodology Logic

A summary of the logic of the RESIDUAL DISPOSAL METHODOLOGY is presented in Figure 6-29. An expanded flowchart, Figure 6-30, lists the steps to be taken in determining performance and costs. The worksheet for recording the operations is presented in Table 6-17. Notes on specific steps and worksheet items are included after the worksheets.

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FIGURE 6-29

RESIDUALS DISPOSAL METHODOLOGY
LOGIC SUMMARY

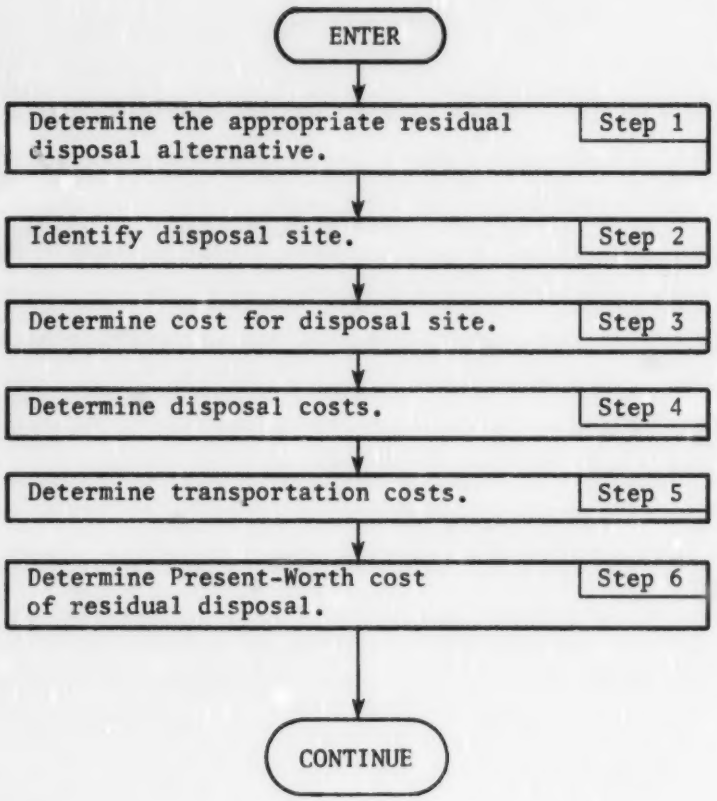

FIGURE 6-30

RESIDUALS DISPOSAL METHODOLOGY
FLOWCHART

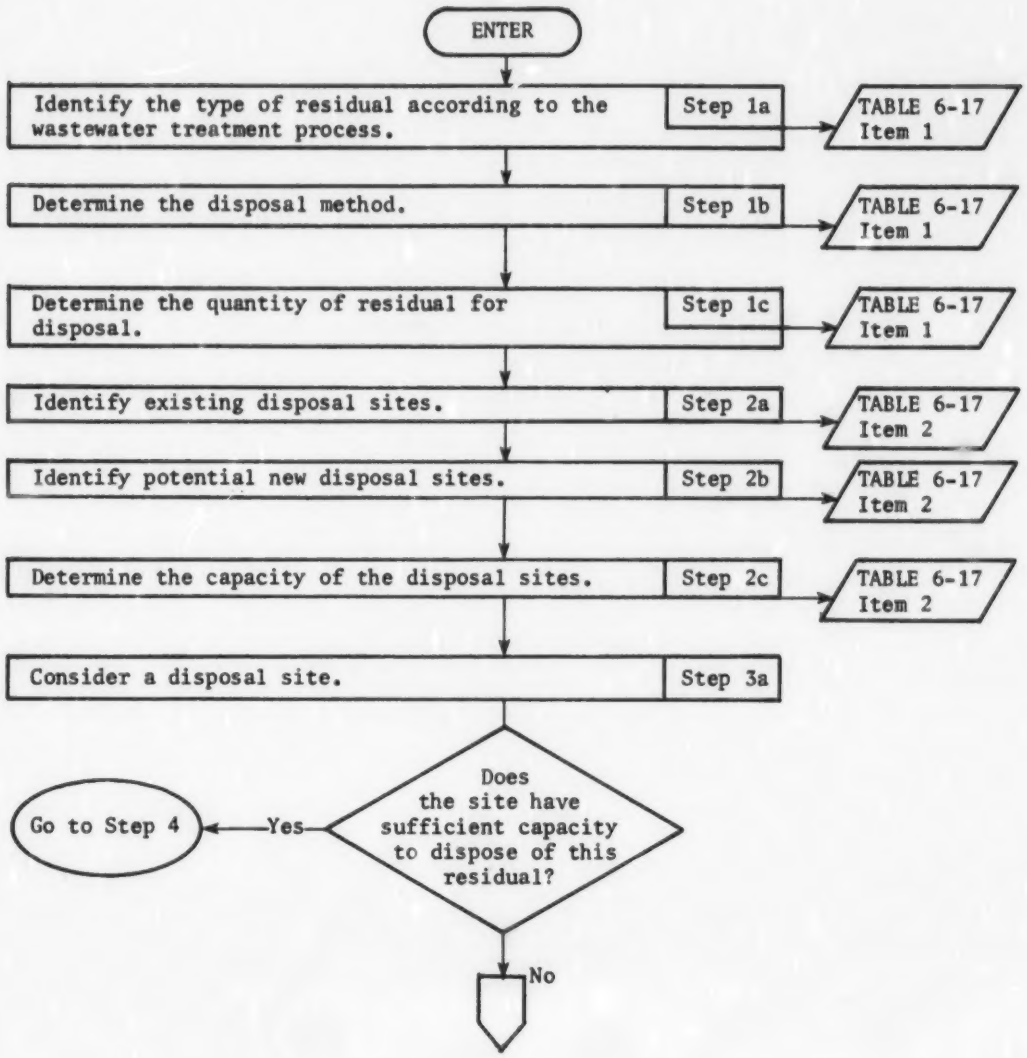

FIGURE 6-30 (continued)

RESIDUALS DISPOSAL METHODOLOGY
FLOWCHART

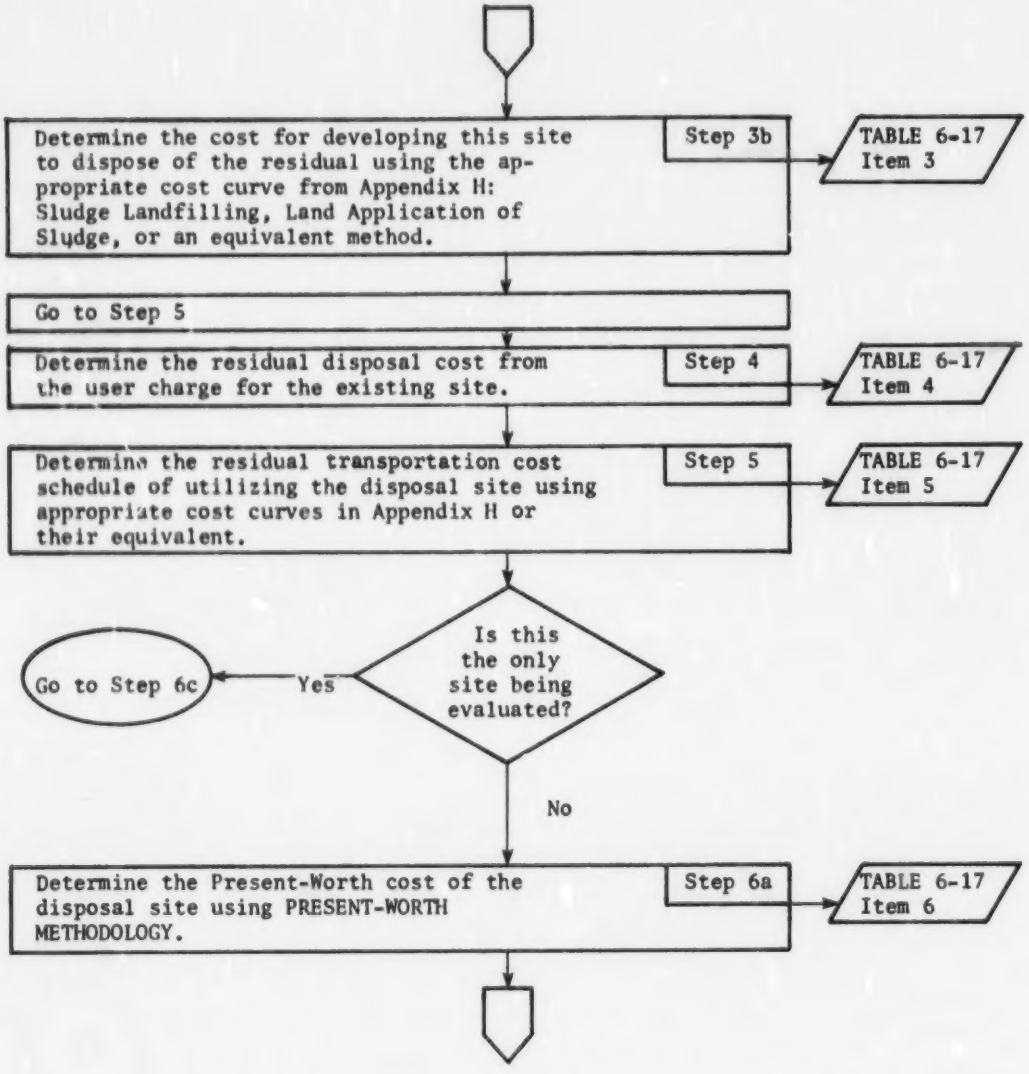
Determine the cost for developing this site to dispose of the residual using the appropriate cost curve from Appendix H: Sludge Landfilling, Land Application of Sludge, or an equivalent method.
Step 3b
TABLE 6-17 Item 3
Go to Step 5
Determine the residual disposal cost from the user charge for the existing site.
Step 4
TABLE 6-17 Item 4
Determine the residual transportation cost schedule of utilizing the disposal site using appropriate cost curves in Appendix H or their equivalent.
Step 5
TABLE 6-17 Item 5
Is this the only site being evaluated?
Yes
Go to Step 6c
No
Determine the Present-Worth cost of the disposal site using PRESENT-WORTH METHODOLOGY.
Step 6a
TABLE 6-17 Item 6

FIGURE 6-30 (continued)

RESIDUALS DISPOSAL METHODOLOGY
FLOWCHART

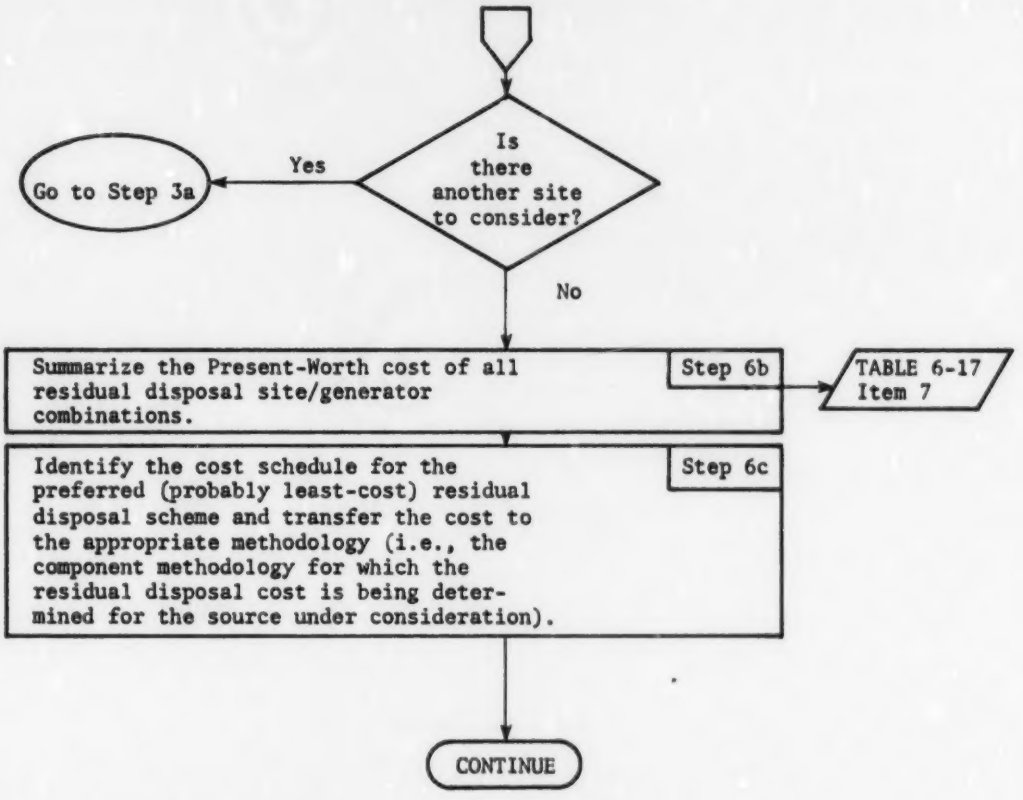
Is there another site to consider?
Yes
Go to Step 3a
No
Summarize the Present-Worth cost of all residual disposal site/generator combinations.
Step 6b
TABLE 6-17 Item 7
Identify the cost schedule for the preferred (probably least-cost) residual disposal scheme and transfer the cost to the appropriate methodology (i.e., the component methodology for which the residual disposal cost is being determined for the source under consideration).
Step 6c
CONTINUE

TABLE 6-17
RESIDUALS DISPOSAL METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgments presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach available (or even as the preferred approach). However, any approaches used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other EPA, State, and local guidelines and regulations.

Item 1 - Residual Characteristics.

i. Residual generator method of treatment:

_____

_____

ii. Residual description: _____

iii. Feasible disposal techniques: _____

IV. Residual quantity: (ultimate)

Design Year Flow Rate _____ mgd

Residual Generation _____ lb/mgd (dry basis)

Disposal Quantity _____ lb/day (dry basis)

Item 2 - Residual Disposal Sites.

i. Site characteristics summary.

	Site	Location	Distance from Generator	Estimated Useful Capacity	Comments
a) Existing Land Spreading Sites.	___	_____	_____	_____	_____
b) Existing Landfill Sites.	___	_____	_____	_____	_____
c) Potential Sites.	___	_____	_____	_____	_____
i) Landfill.	___	_____	_____	_____	_____
ii) Land Spreading.	___	_____	_____	_____	_____

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TABLE 6-17 (continued)
RESIDUALS DISPOSAL METHODOLOGY
WORKSHEET

Item 2 - continued

iii. Site capacity evaluation - existing site _____

a) Useful life at existing disposal rate: _____ years

b) Existing disposal rate: _____ lb/day or ton/day or cu yd/day

c) Proposed disposal rate: _____ (same units as above)

(use average rate for entire planning period)

d) Useful life at proposed disposal rate = (a) x $\frac{(b)}{(c)}$ = _____

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TABLE 6-17 (continued)
RESIDUALS DISPOSAL METHODOLOGY
WORKSHEET

Item 3 - Cost for Development of Residual Disposal Site.

i. Program Schedule.

Phase	Timing Yr to Yr	Design Flows (mgd) Start	End
1	_____ to _____	_____	_____
2	_____ to _____	_____	_____
3	_____ to _____	_____	_____
n	_____ to _____	_____	_____

ii. Site Development Schedule.

Phase	Design Flow (mgd)	Land Required[1] (acre)	Land Cost[2]
1	_____	_____	_____
2	_____	_____	_____
3	_____	_____	_____
n	_____	_____	_____

[1]Land Required = _____ acre/mgd

[2]Land Cost = $_____/acre

iii. Project Cost Schedule - Disposal Site.

Phase	Timing Yr to Yr		Capital[1]	O&M Start	O&M End	Replacement Cost[2] Year	Replacement Cost[2] Cost	Salvage Value[2]
Land Cost								
1								
2								
3								
n								

[1]Capital computed as described for TREATMENT FACILITY METHODOLOGY; includes construction add on's to reflect installed capital. Capital = curve $ x (1.0 + Construction Add on's.)

[2]Cost computed as described for TREATMENT FACILITY METHODOLOGY; attach appropriate computations.

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TABLE 6-17 (continued)
RESIDUALS DISPOSAL METHODOLOGY
WORKSHEET

Item 4 - Residual Disposal Cost for Existing Site.

Program Costs

Phase	Timing Yr to Yr	Design Flow (mgd) Start	Design Flow (mgd) End	Residual Quantity[1] Start	Residual Quantity[1] End	Disposal Cost[2] Start	Disposal Cost[2] End
1	_____	____	____	____	____	____	____
2	_____	____	____	____	____	____	____
3	_____	____	____	____	____	____	____
n	_____	____	____	____	____	____	____

[1]Determined using _____lb/mg

[2]Determined using ($_____/lb disposal cost) x (Residual Quantity lb/yr)

Item 5 - Residual Transportation Cost (using appropriate cost curves in Appendix H, Figures H-86 to H-90, or equivalent.

i. Transportation Method: _____

Residual Characteristics: Type _____ Solids _____

ii. Transportation Cost Schedule.

Phase	Timing Yr	Timing to Yr	Capital[1]	O&M Start	O&M End	Design Flow Start	Design Flow End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
1										
2										
3										
n										

[1]Develop capital estimate based on end design flow for each phase; include construction add on's to reflect installed cost.

[2]Develop O&M estimate (start and end) for each phase.

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TABLE 6-17 (continued)
RESIDUALS DISPOSAL METHODOLOGY
WORKSHEET

Item 6 - Residual Disposal Site Present-Worth Cost

i. Alternative Characteristics:

Residual _____

Solids _____

Transportation Method _____

Disposal Method _____

ii. Present-Worth Cost (from PRESENT-WORTH METHODOLOGY) $ _____

Reference Sheets _____

Item 7 - Site Alternatives Summary - Residuals Disposal

Site	Location	Present-Worth Cost

By _____ Date _____ Strategy No. _____
Checked by _____ Date _____ Source No. _____
Remarks: _____ Page _____

Notes on Methodology Logic

Step 1a (Item 1i, ii) - This step of the evaluation will identify the nature of the residual generated by the wastewater treatment facility, referred to as the generator. The residual will be identified as either biological or chemical, depending on the nature of the treatment at the point source. In addition, the solids content of the residual should be estimated by considering the residual treatment process utilized at the treatment facility. In many instances where more complex treatment processes are required, more than one type of sludge might be identified.

Step 1b (Item 1iii) - The feasible disposal techniques are identified in this step. The table below describes a classification for selecting these techniques that might be useful in identifying the general potential for a particular residual. However, many local, state, and federal regulations exist concerning pathogens, solids content, etc; the user is advised to modify this table to reflect the local condition.

	Residual Type				
	Biological			Chemical	
	Wet	Cake	Ash	Cake	Ash
Land Spreading	X	X	-	-	-
Landfill	-	X	X	X	X

A wet residual represents a thickened or unthickened residual (solids at 1 to 10 percent). A cake represents a dewatered condition (solids at 15 to 50 percent), and an ash represents the product from an incinerator. The user should determine the type of residual generated by the treatment process under consideration. (Although not addressed in this methodology, the user should also consider other residuals handling techniques such as incineration or composting.)

Step 1c (Item 1iv) - In this step, the quantity of residual generated by the source control method is estimated. This information can be developed by the user for special cases. The treatment systems curves in Appendix H indicate an estimate for typical wastewater treatment processes.

Step 2a (Item 2i) - The identification of existing disposal sites is described in this step. The sites identified for a specific residual might

include any existing residual disposal sites, but more typically would include the site currently utilized for disposing the existing residual.

Step 2b (Item 2i) - The identification of potential new disposal sites is described in this step, primarily to insure that the user gives some consideration to the site-specific factors associated with development of a new disposal site. In general, the local authorities will favor utilizing an acceptable existing site due to the adverse social and environmental impacts of disposal site development.

Step 2c (Item 2iii) - This step evaluates the remaining disposal capacity at an existing site. This capacity is most easily identified in terms of the useful life of the site while operating at the increased disposal rate.

Step 3a - No discussion.

Step 3b (Item 3) - This step is utilized if a new site is being developed or if the existing site is being expanded because of insufficient capacity. The site development/expansion schedule should be prepared considering the project design flows and anticipated residual generation. The project cost schedule can then be developed using the cost curves in Appendix H or an equivalent method. The user should modify any cost curve capital estimate to reflect total construction cost (e.g., engineering design and construction contingency) as is done in the TREATMENT FACILITY METHODOLOGY (Table 6-4, Item 3) using reasonable construction estimates.

Step 4 (Item 4) - This step is utilized only when the disposal site has sufficient capacity to accept the residual. In this case, the residual disposal cost will consist of the user charge for the particular disposal site of interest.

Step 5 (Item 5) - This step identifies the transportation cost for residual disposal, which can be developed using the cost curves in Appendix H or their equivalent.

Step 6 (Item 6) - This step identifies the Present-Worth cost of the residual disposal alternative under consideration. This step will be utilized to compare the Present-Worth cost of two or more disposal alternatives. When only one alternative is under consideration, this step will not be used.

Step 6b (Item 7) - This step summarizes the Present-Worth cost of alternative residual disposal site evaluations when several sites are under consideration. Note: this step is not required when only one site is being considered because the site's cost schedule will be transferred to the appropriate project cost schedule for the Present-Worth determination.

Step 6c - This step involves the transfer of the cost schedule for the preferred residual disposal site to the project cost schedule for the control alternative for which the residual disposal cost is being determined, e.g., treatment plant construction.

6.4.2.13 Transportation Cost Methodology

Discussion

The TRANSPORTATION COST METHODOLOGY is intended to guide the user in developing a reliable cost estimate for a pipeline conveyance system. This procedure is applicable for wastewater (including land application and reuse) and liquid sludge transportation. It is used in conjunction with other methodologies, such as regionalization and discharge relocation, whenever it is necessary to determine the cost of transporting wastewaters or sludges by pipeline.

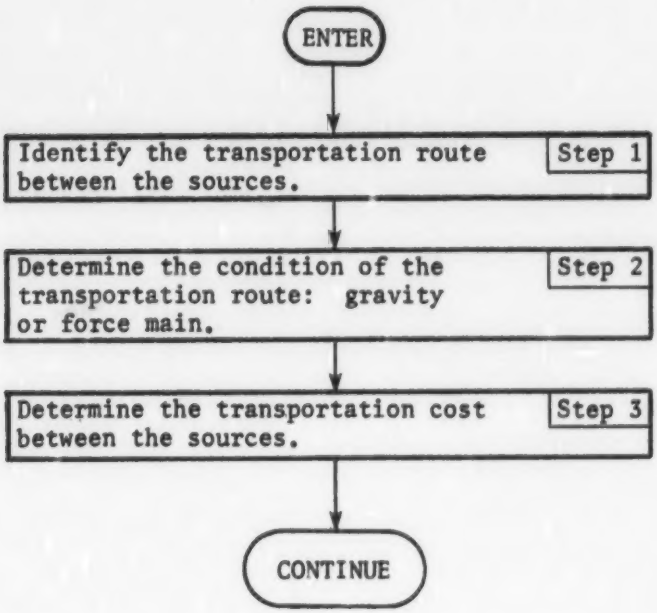
The initial determination in this methodology is the identification of a suitable transportation route between the contributing source and the receiving point. The selected route is then divided into segments defined by breaks in the slope of the pipeline. Each of these segments is then analyzed to determine if a gravity-flow condition exists. When it is determined that gravity flow would not be acceptable for the segment of interest, a force main is assumed. The cost for each segment thus consists of the pipeline and the pumping costs required for force main segments. Although not included in this methodology, the user should also consider other factors which will affect costs, such as local soils and other topographic features (e.g., depth to bedrock, stream crossings) and right-of-way acquisition. The cost associated with each segment is then combined to obtain the overall transportation cost for the relocation of the flow from the contributing source to the receiving point.

Methodology Logic

A summary of the logic of the TRANSPORTATION COST METHODOLOGY is presented in Figure 6-31. An expanded flowchart, Figure 6-32, lists the steps to be taken in determining performance and costs. The worksheets for recording the operations are presented in Table 6-18. Notes on specific steps or worksheet items are presented after the worksheets.

FIGURE 6-31

TRANSPORTATION COST METHODOLOGY
LOGIC SUMMARY


ENTER
Identify the transportation route between the sources.
Step 1
Determine the condition of the transportation route: gravity or force main.
Step 2
Determine the transportation cost between the sources.
Step 3
CONTINUE

842<

FIGURE 6-32

TRANSPORTATION COST METHODOLOGY
FLOWCHART

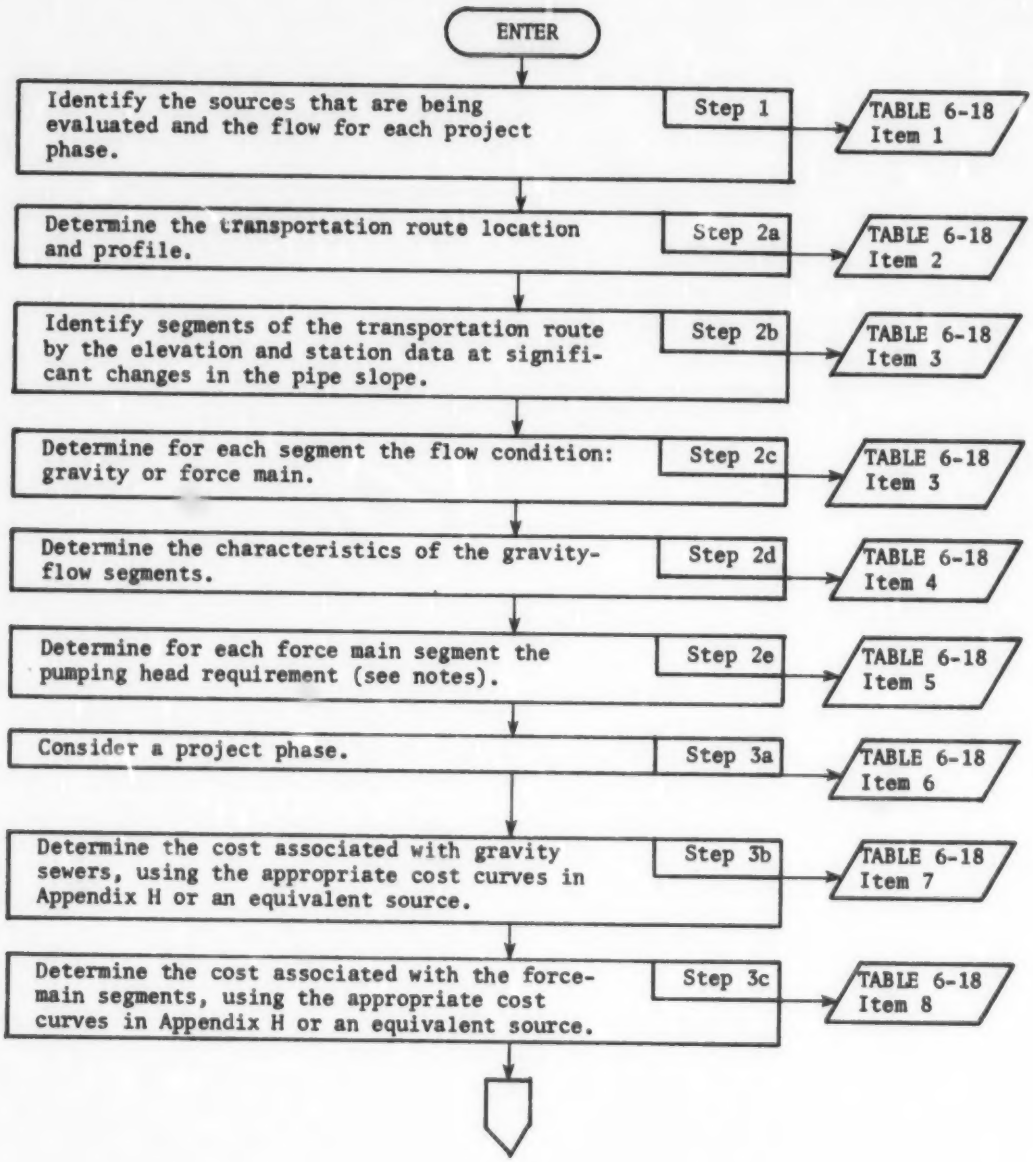

ENTER
Identify the sources that are being evaluated and the flow for each project phase.
Step 1
TABLE 6-18 Item 1
Determine the transportation route location and profile.
Step 2a
TABLE 6-18 Item 2
Identify segments of the transportation route by the elevation and station data at significant changes in the pipe slope.
Step 2b
TABLE 6-18 Item 3
Determine for each segment the flow condition: gravity or force main.
Step 2c
TABLE 6-18 Item 3
Determine the characteristics of the gravity-flow segments.
Step 2d
TABLE 6-18 Item 4
Determine for each force main segment the pumping head requirement (see notes).
Step 2e
TABLE 6-18 Item 5
Consider a project phase.
Step 3a
TABLE 6-18 Item 6
Determine the cost associated with gravity sewers, using the appropriate cost curves in Appendix H or an equivalent source.
Step 3b
TABLE 6-18 Item 7
Determine the cost associated with the force-main segments, using the appropriate cost curves in Appendix H or an equivalent source.
Step 3c
TABLE 6-18 Item 8

FIGURE 6-32 (continued)

TRANSPORTATION COST METHODOLOGY
FLOWCHART

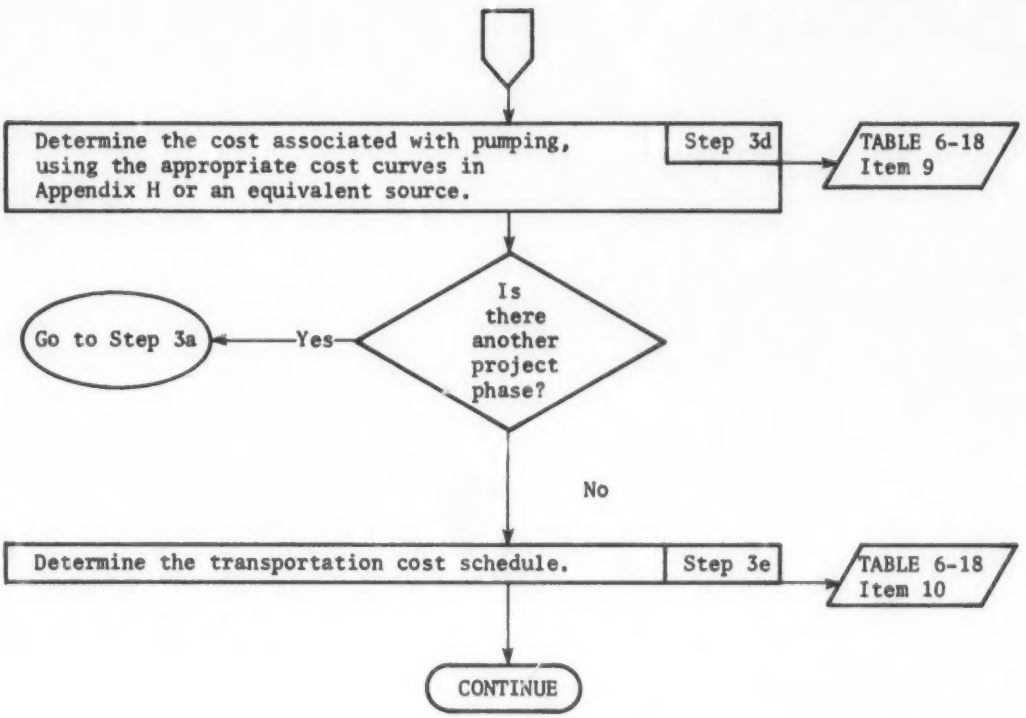

Determine the cost associated with pumping, using the appropriate cost curves in Appendix H or an equivalent source.
Step 3d
TABLE 6-18 Item 9
Is there another project phase?
Yes
Go to Step 3a
No
Determine the transportation cost schedule.
Step 3e
TABLE 6-18 Item 10
CONTINUE

TABLE 6-18
TRANSPORTATION COST METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgments presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach available (or even as the preferred approach). However, any approaches used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other EPA, State, and local guidelines and regulations.

Item 1 - Project/Phase/Source Identification.

i. Project: _____

ii. Source Identification

Source	Elevation	Design Flow (mgd) @ Phase No.				
		1	2	3	n	Design Yr

Item 2 - Transportation Route Profile.
(also locate route on topographic map)

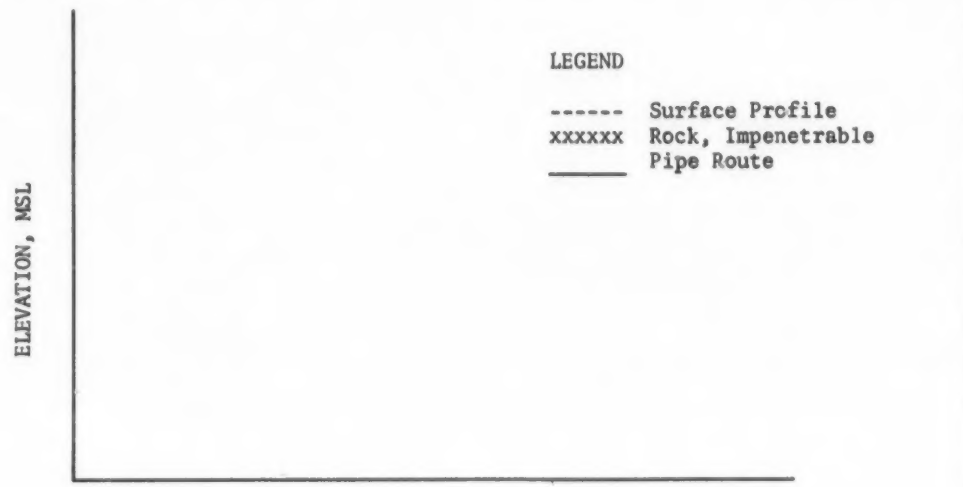


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TABLE 6-18 (continued)
TRANSPORTATION COST METHODOLOGY
WORKSHEET

Item 3 - Critical Segments of the Transportation Route.

Flow Rate: _____ Assumed n-value: _____

Segment	Elevation/Station[1] E/S(A)	to E/S(B)	Slope[2]	Velocity[3]	Flow Type[4]
a)					
b)					
c)					
d)					

Notes:

1. Define Elevation Station Data from upstream E/S(A) to downstream E/S(B).

2. Slope = $\frac{E(B) - E(A)}{S(B) - S(A)}$ Units: ft/ft

3. Determine velocity only for positive slope condition; negative slope indicates force main (see discussion); use the attached nomograph (Hydraulic Computations).

4. Flow type: Gravity if positive slope and acceptable velocity (2 fps minimum); force main for other conditions.

Reference calculation sheets: _____

Item 4 - Gravity Segments.

Flow Rate: _____ mgd

Segment	Flow Rate (mgd)	Length (ft)
a)		
b)		
c)		
d)		
TOTAL		

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TABLE 6-18 (continued)
TRANSPORTATION COST METHODOLOGY
WORKSHEET

Item 5 - Force Main Segments.

Segment	Length	Static Head[1]	Dynamic Head[2]	Pumping Head[3]
a)				
b)				
c)				
d)				

Notes: [1]Static head = elevation difference from upstream to downstream.

[2]Dynamic head = See Discussion, Step 2 (Item 5).

[3]Pumping head = Static head + Dynamic head.

Reference calculation sheets: _____

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TABLE 6-18
TRANSPORTATION COST METHODOLOGY
WORKSHEET

COST DETERMINATION

Item 6 - Project/Phase Identification.

Project: _____

Phase: _____

Item 7 - Gravity Sewer Costs.

i. Reference Cost Curve: Figure H-84 (or equivalent curve)
Service Life: _____ years
Gravity Sewer Length: _____ feet
Design Flow Rate: _____

ii. Cost Determination.

Construction Cost: $_____
(Compute only for Phases that include sewer construction; adjust curve cost to reflect installed cost.)

O&M Cost - Start: $ _____
O&M Cost - End: $ _____
Replacement Cost: None
Salvage Value (SV)[1] $ _____

$$^{1}SV = \frac{\text{(Service Life - Years to Project End)}}{\text{(Service Life)}} \times \text{Capital}$$

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TABLE 6-18 (continued)
TRANSPORTATION COST METHODOLOGY
WORKSHEET

Item 8 - Force Main Cost.

i. Phase: _____

Cost Curve: Figure H-85 (or equivalent curve)

Service Life: _____ years

Length: _____ ft

a) _____ ft @ _____ mgd

b) _____ ft @ _____ mgd

c) _____ ft @ _____ mgd

ii. Cost Determination.

	Segment a	Segment b	Segment c
Capital Cost[1]			
O&M Cost - Start			
O&M Cost - End			
Replacement Cost	None	None	None
Salvage Value (SV)[2]			

[1]Compute only for Phases that include force main construction; adjust curve cost to reflect installed cost.

[2]$SV = \frac{\text{(Service Life - Years to Project End)}}{\text{(Service Life)}} \times \text{Capital}$

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TABLE 6-18 (continued)
TRANSPORTATION COST METHODOLOGY
WORKSHEET

Item 9 - Pump Station/Pumping Cost.

i. Phase: _____

Service Life: _____ years

Pumping Head/Flow:

Segment	Total Head	Flow Rate Start	Flow Rate End

ii. Cost Determination. (Cost curve Figure H-30, or equivalent)

	(a)	(b)	(c)
Segment:	_____	_____	_____
Capital Cost[1]	_____	_____	_____
O&M Adjustment for head[2]	( )	( )	( )
O&M - Start[3]	_____	_____	_____
O&M - End[3]	_____	_____	_____
Replacement Cost/Year[4]	_____	_____	_____
Salvage Value (SV)[5]	_____	_____	_____

Notes: [1]Compute only for Phases that include pumping capacity expansion; adjust curve cost to reflect installed cost.

[2]Compute as described by the cost curve.

[3]O&M Cost = Curve Cost + Adjustment

[4]Replacement Cost = $\frac{\text{Years Remaining in Project-Service Life}}{\text{Service Life}}$ x Capital

[5]SV = $\frac{\text{(Service Life - Years Remaining in Project)}}{\text{(Service Life)}}$ x Capital

If Salvage Value is negative, enter as 0 and compute replacement cost.

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TABLE 6-18 (continued)
TRANSPORTATION COST METHODOLOGY
WORKSHEET

Item 10 - Transportation Cost Summary.

1. Cost Schedule.

Phase	Item	Capital Cost	Start - O&M	End - O&M	Salvage Value
1	#7				
	#8				
	#9				
	TOTAL PHASE 1				
2	#7				
	#8				
	#9				
	TOTAL PHASE 2				
3	#7				
	#8				
	#9				
	TOTAL PHASE 3				
n	#7				
	#8				
	#9				
	TOTAL PHASE n				

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TABLE 6-18 (continued)
TRANSPORTATION COST METHODOLOGY
WORKSHEET

Item 10 - Transportation Cost Summary (continued).

Replacement Schedule		
Item	Year	Cost
___	___	___
___	___	___

ii. Present-Worth Cost: $_____

(Compute only when required.)

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Notes on Methodology Logic

Step 1 (Item 1) - This step identifies the conditions for the transportation cost evaluation. The flow rate for each source at each phase should be available from previous evaluations.

Step 2a (Item 2) - This step identifies the pipeline route for the cost evaluation. The user should identify the route on available topographic maps (e.g., USGS Quadrangle Sheets), with general consideration given to the natural path between the two locations and environmental constraints. Typically, this would indicate that the transportation route follows a stream or other relatively low area. The surface profile between the two sources is then determined and plotted on the transportation route identification graph. It is also desirable that the underlying condition along the path be identified if the information is readily available. The purpose of this determination is to locate any underground conditions that would constrain the type of pipeline that could be installed. For example, a shallow rock deposit would limit the depth to which a gravity sewer could be installed, so this should be identified on the transportation route graph. This information is entered onto the graph in terms of the station and elevation of each critical point (i.e., minimum and maximum elevations for any condition). The pipeline profile can then be developed on this graph, with Source 1 defined as the receiving point and Sources 2, 3, etc., the contributing points.

Step 2b (Item 3) - In this step the user characterizes the pipeline route in terms of critical segments that approximate the anticipated condition. These critical segments should be as short as required to adequately describe the pipeline condition, but the user should try to identify a minimum of these to provide a degree of detail consistent with the other methodologies.

Step 2c (Item 3) - Since a gravity sewer is less expensive than a force main, this step is concerned primarily with identifying the segments that can utilize a gravity sewer. Each segment is defined by its endpoint elevation and station, working from the upstream to the downstream end of the pipeline. The slope for each identified segment should be computed. A positive slope indicates that the upstream end is higher than the downstream end of the

segment. The flow velocity can be computed using the nomograph (Figure 6-33), or by any other accepted method. The flow type for each segment is gravity flow if the slope is positive and the resultant flow velocity is sufficient (minimum 2 feet per second). Force main segments are those that cannot be identified as gravity.

Step 2d (Item 4) - This step identifies the peak flow rate (typically 2.5 to 3.0 times the average flow rate at the design-year condition) and the length of the critical gravity flow segments.

Step 2e (Item 5) - In this step, each force main segment is characterized as to the energy (pumping head) required to maintain flow through that segment. The static head refers to the energy required to lift the water from the downstream point to the upstream point, and can be considered the elevation difference between these points. The dynamic head represents the energy losses (dynamic losses) in the pipeline associated with flow through the pipe. These dynamic losses are a function of the velocity in the pipe and the pipe characteristics. As a first approximation, the user can define the dynamic losses to be equal to 20 percent of the static head since, under the average conditions, the design engineer would limit total dynamic losses to a number in this range. For the situation where a more accurate estimate is required, or when there is a long force main/low lifting head situation, the user should determine this friction loss using standard engineering methods.

Step 3a (Item 6) - This step identifies the project and phase to which the calculations in Items 7 to 10 apply.

Step 3b (Item 7) - In this step, the gravity sewer capital cost is determined for phases that include pipeline construction. The operation and maintenance cost associated with the gravity sewer should be determined for every project phase.

Step 3c (Item 8) - In this step, the force main capital cost is determined for phases that include pipeline construction. The operation and maintenance cost associated with the force main should be determined for every project phase.

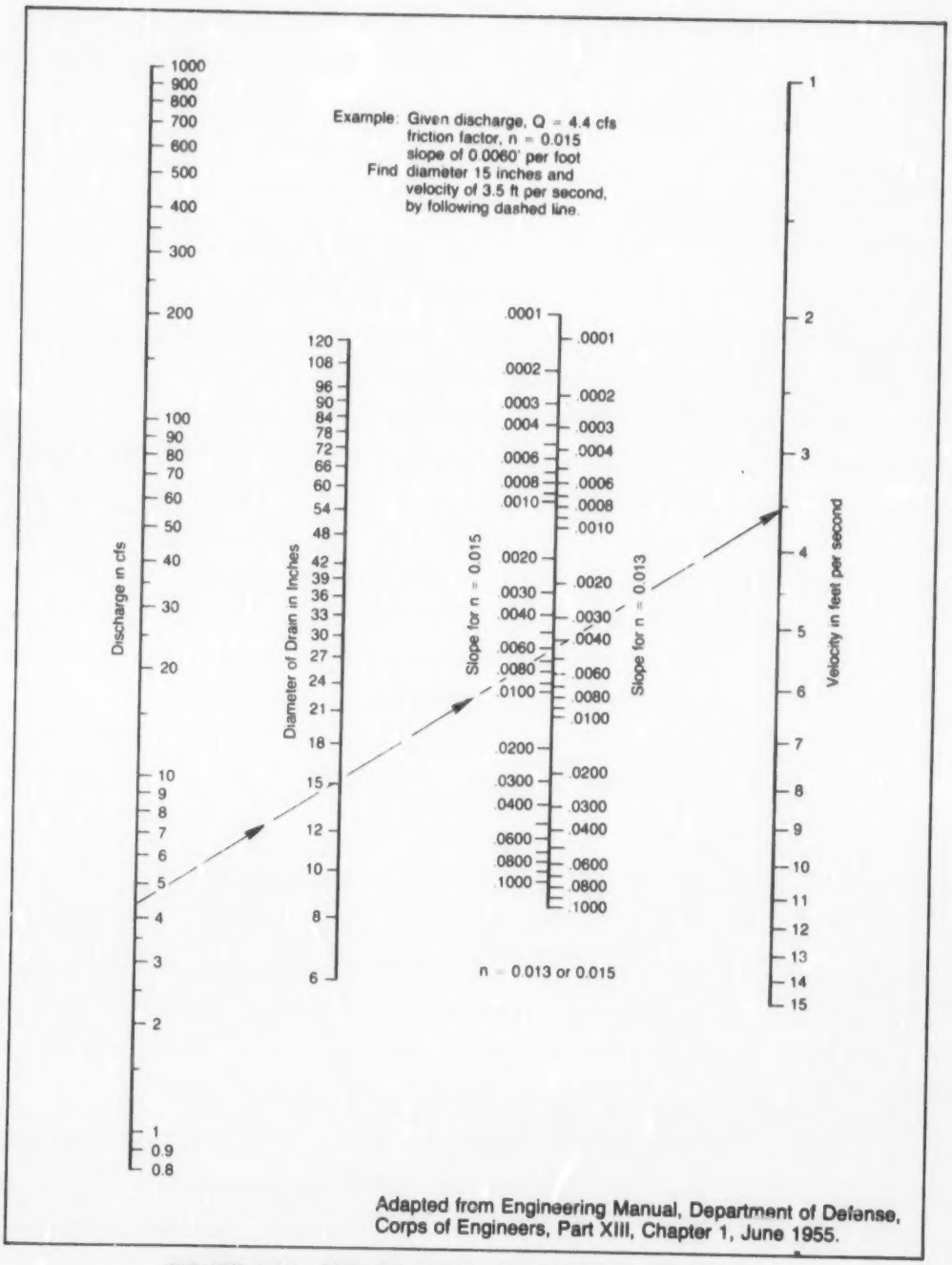
Example: Given discharge, Q = 4.4 cfs
friction factor, n = 0.015
slope of 0.0060' per foot
Find diameter 15 inches and
velocity of 3.5 ft per second,
by following dashed line.
Discharge in cfs
Diameter of Drain in Inches
Slope for n = 0.015
Slope for n = 0.013
Velocity in feet per second
n = 0.013 or 0.015
Adapted from Engineering Manual, Department of Defense,
Corps of Engineers, Part XIII, Chapter 1, June 1955.

FIGURE 6-33 SIZE OF CIRCULAR DRAIN FLOWING FULL

Step 3d (Item 9) - In this step, the various cost items associated with wastewater pumping are determined. The project schedule should identify the desired pumping capacity during the various phases of the planning period. After this step, the user is directed to evaluate the next project phase for the cost items.

Step 3e (Item 10) - This step summarizes the costs determined in Items 6, 7, 8, and 9 in a Transportation Cost Schedule. This schedule can be transferred to the appropriate methodology for inclusion in the project cost schedule or can be used to develop the Present-Worth cost.

6.5 Illustrative Example

This illustrative example is presented to demonstrate how the approach presented in Chapter 6 is employed to develop and evaluate control alternatives for a 208 planning area. The setting for the example is the hypothetical Jefferson City area on the South River, which has been used throughout this manual.

The methodology is employed just as it would be in an actual problem setting. Water quality objectives are defined, load-reduction strategies are developed, and the FRAMEWORK METHODOLOGY guides the user in utilizing the component methodologies to evaluate control alternatives for each wastewater source of interest.

Notes are recorded directly on the worksheets and on separate sheets entitled "Illustrative Example Supplemental Notes" to give the user additional information about the source of a numerical value, the reason for a particular operation, or other explanations which clarify the procedure. In order to reduce the volume of the example, the various methodology worksheets are filled out completely only the first time they are utilized. If a set of worksheets is needed more than once, a note is included to indicate how the user would proceed. An assumption is made about the result if it is needed for further determinations.

6.5.1 Water Quality Objectives

Dissolved Oxygen criteria and suggested objectives for other water quality parameters for the South River are presented in Table 6-1. As explained earlier in this chapter, the water quality standards that are in force for a particular situation do not always address all important water quality parameters. A standard often must be considered a minimum objective for an area. Separate objectives may be set to address parameters other than the most commonly addressed one, i.e., Dissolved Oxygen. Therefore, a range of objectives is available for an area, for example, from simply meeting the water quality standard to controlling pollution from storm water runoff also. Control alternatives to meet these objectives will probably require a wide range of costs.

For the South River area, various objectives for control of individual parameters and combinations of parameters are proposed for further evaluation. These objectives are recorded in Table 6-19.

6.5.2 Load-Reduction Strategies

As explained earlier in Chapter 6, a load-reduction strategy is a combination of percentage load reductions at various sources which will meet a given water quality objective. There may be a number of load-reduction strategies which will meet any one objective. A combination of a water quality objective and a strategy is referred to simply as a load-reduction strategy.

For any area, there may be a number of water quality objectives, several strategies to achieve each objective, and a wide range of costs to implement the strategies. This suggests that a decision-maker will have to make decisions on two levels. First, he must decide on the water quality objective which will be sought; then he must decide on the most cost-effective control alternative to achieve that objective. The first decision generally will identify the order of magnitude of dollars to be spent to achieve water quality (however it might be defined). Control of more parameters with fewer allowable violations usually requires more money, and selection of a particular control alternative identifies the approach which supposedly will have the least total cost to society. Since the decision-maker cannot perform his function without input, the planner or engineer must develop appropriate cost information for all feasible and potentially desirable strategies.

The Load-Reduction Strategy Matrix, Table 6-19, represents a number of different water quality objectives for the South River area, and several strategies for achieving these objectives. The strategies were formulated by using the water quality impact analysis techniques in Chapter 5. Obviously, in an area which has a number of sources, there is a very large number of possible combinations of load reductions which will achieve the desired objective. The strategies formulated for a planning area should include those combinations which present a choice, by including significantly different technological solutions to achieve the desired water quality objectives.

The objectives and strategies presented in Table 6-19 range from control of one water quality parameter and two sources, to control of five parameters

TABLE 6-19

LOAD REDUCTION STRATEGY MATRIX

Allocation Designation	Objective	STP I (% Removal)	STP II (% Removal)	Separate Storm Sewer Runoff (% Removal)	Combined Sewer Overflow (% Removal)
1a	DO[(1)]-1	55% CBOD 55% NBOD	55% CBOD 55% NBOD	-	-
1b	DO-1	24% CBOD 24% NBOD	75% CBOD 75% NBOD	-	-
1c	DO-1	83% CBOD 42% NBOD	83% CBOD 42% NBOD	-	-
1d	DO-1	16% CBOD 75% NBOD	16% CBOD 75% NBOD	-	-
2a	DO-1,DO-2	55% CBOD 55% NBOD	55% CBOD 55% NBOD	-	39% UOD
2b	DO-1,DO-2	55% CBOD 55% NBOD	55% CBOD 55% NBOD	25% UOD	25% UOD
2c	DO-1,DO-2	75% CBOD 75% CBOD	75% CBOD 75% NBOD	-	24% UOD
3a	TC[(2)]-1	-	-	95% TC	99.83% TC
3b	TC-1	-	-	99.62% TC	99.62% TC
4	TSS[(3)]-1	-	-	65% TSS	-
5a	N[(4)]-1	58% N	58% N	-	-
5b	P[(5)]-1	80% P	80% P	-	-
6 = 2a	DO-1,DO-2 TC-1	55% CBOD 55% NBOD	55% CBOD 55% NBOD	- 95% TC	39% UOD 99.83% TC
7 = 2a, 3a 3a, 4	DO-1,DO-2 TC-1,TSS-1	55% CBOD 55% NBOD	55% NBOD 55% NBOD	65% TSS 95% TC	39% UOD 99.83% TC
8 = 2a, 3a, 5a, 5b	DO-1,DO-2, TC-1,N-1,P-1	55% CBOD 55% NBOD 58% N 80% P	55% CBOD 55% NBOD 58% N 80% P	95% TC	39% UOD 99.83% TC
9 = 2a, 3a, 4, 5a, 5b	DO-1,DO-2, TC-1,TSS-1, N-1,P-1	55% CBOD 55% NBOD 58% N 80% P	55% CBOD 55% NBOD 58% N 80% P	65% TSS 95% TC	39% UOD 99.83% TC

NOTES:

(1) DO = dissolved oxygen

(2) TC = total coliform organisms

(3) TSS = total suspended solids

(4) N = total nitrogen

(5) P = total phosphorus

and four sources. In an actual situation, a user would probably elect to start his analysis with the simplest case and proceed to the most complex. Determinations made for the sources under the simplest case very often will be relevant in evaluating more complex strategies.

6.5.3 Development and Evaluation of Control Alternatives

When the Load-Reduction Strategy Matrix has been developed, the user is ready to begin the development and evaluation of control alternatives for his 208 area. He does this by utilizing the FRAMEWORK METHODOLOGY, and the component methodologies determined to be appropriate for the area involved. Worksheets from both the framework and the component methodologies are filled out and filed as illustrated in the pages that follow.

To further aid the user, a list is presented (in Table 6-20) of the methodologies employed in this illustrative example; each component methodology is used at least once. The illustrative example worksheets are numbered in the lower right corner just as they would be in actual use. The report page number appears at the bottom center of the page and is prefixed by a "6-". Page references within the illustrative example mean the illustrative-example page numbers in the lower right corner.

TABLE 6-20
INDEX TO COMPONENT METHODOLOGIES USED
IN ILLUSTRATIVE EXAMPLE

Strategy	Source	Methodology[1]	Illustrative Example Page Number
N/A	N/A	Framework	1
9	1	Treatment Facility	9
		Residuals Disposal	19
		Present-Worth	27
		Land Application	31
		Transportation	38
		Present-Worth	50
		Wastewater Reuse	55
		Treatment Facility	58
		Impact Area Modification	67
		Regionalization	77
9	3	Land Management	87
		Collection System Control	91
		Storage/Treatment	100

[1]Component methodologies utilized by other component methodologies are included.

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TABLE 6-3
FRAMEWORK METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgments presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach available (or even as the preferred approach). However, any approaches used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other EPA, State, and local guidelines and regulations.

Item 1

i. Identification of water quality objectives, load reduction strategies, and sources.

a. Define water quality objectives by number and parameters to be controlled.

	Receiving Water Constituents to be Controlled					
Water Quality Objective #	D.O. (Dry Weather)	D.O. (Wet Weather)	Total Suspended Solids (Wet Weather)	Total Nitrogen	Total Phosphorus	Total Coliforms (Wet Weather)
1	x					
2	x	x				x
3			x			
4				x	x	
5						x
6	x	x				
7	x	x	x			
8	x	x		x	x	x
9	x	x	x	x	x	x

b. Load reduction strategies represent differing percentage reductions in load at the various sources of interest for a particular water quality objective. These strategies are identified by a letter (a, b, c, etc.) where more than one strategy is proposed for a particular water quality objective.

c. Identify sources by number: Attached Figure 5-7 (page 2) defines the location of each source.

Source #	Source Type (Wet or Dry)	Source Description
1	Dry	Sewer District (SD1), Wastewater Treatment Plant 1
2	Dry	Sewer District (SD2), Wastewater Treatment Plant 2
3	Wet	Combined Sewer Overflow, SD1
4	Wet	Separate Storm Sewer Runoff, SD2
5	Wet	Separate Storm Sewer Runoff, SD2
6	Wet	Combined Sewer Overflow, SD1
7	Wet	Combined Sewer Overflow, SD1

By _____ Date _____ Strategy No. N/A
Checked by _____ Date _____ Source No. N/A
Remarks: _____ Page 1

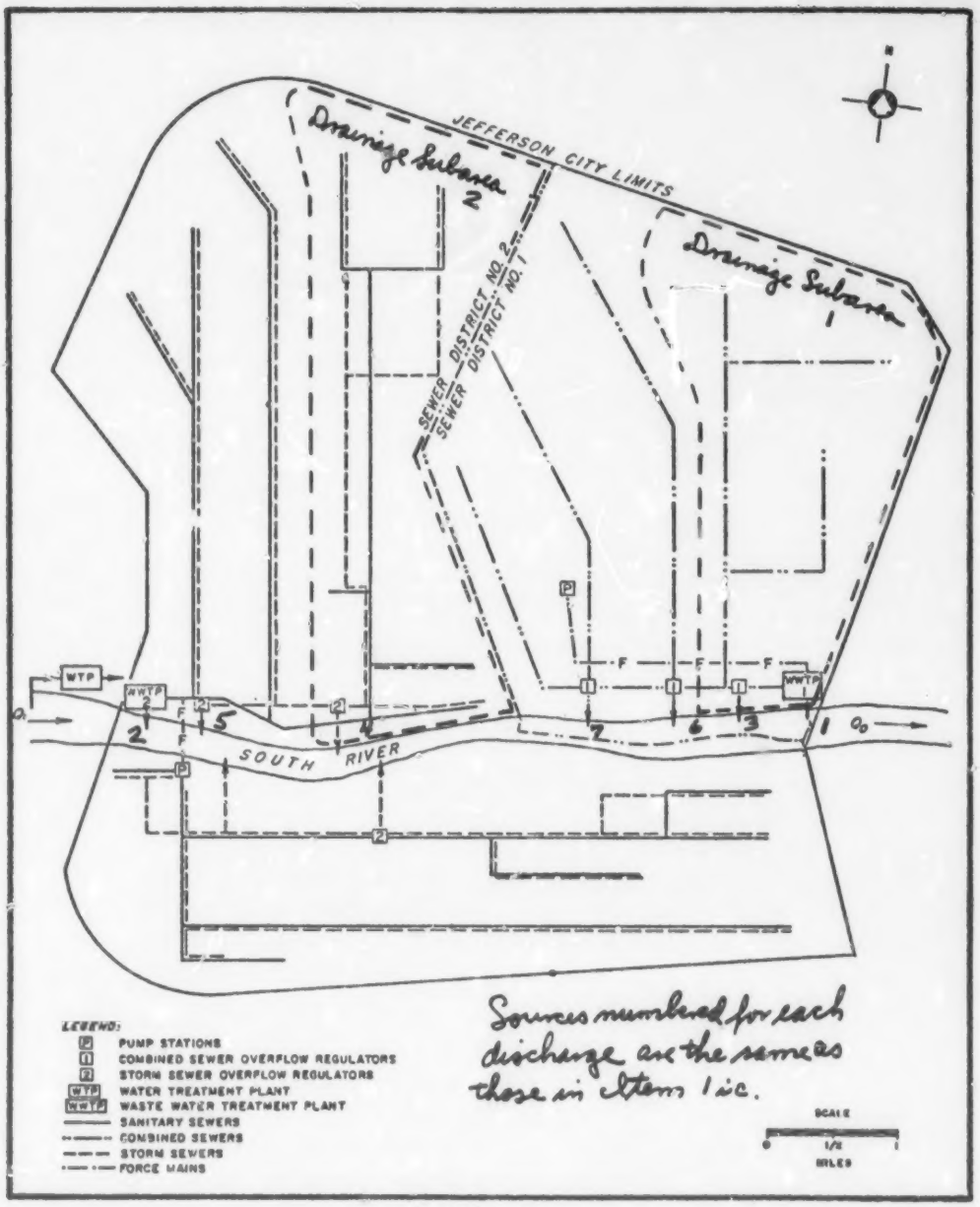

FIGURE 5-7
JEFFERSON CITY STUDY AREA
COLLECTION SYSTEM

By _____	Date _____	Strategy No. _____
Checked by _____	Date _____	Source No. _____
Remarks: _____		Page 2

Illustrative Example Supplemental Notes

The water quality objectives defined in Item 1i are those indicated by Table 6-1. These numbers will be referenced throughout this example by "Number-Letter", where the letter refers to the individual strategy that meets the water quality objective. An objective/strategy combination will be referred to as a load-reduction strategy or simply as the strategy.

The impact analysis in Chapter 5 deals with the combined sewer overflows (identified as Sources 3, 6, 7) and separate storm sewer runoff (Sources 4, 5) as aggregated loads.

For this example, the assumption has been made, for illustrative purposes, that these aggregated loads can be controlled to the desired level by implementing a control program for Sources 1, 2, 3, and 4.

By _____ Date _____ Strategy No. N/A
Checked by _____ Date _____ Source No. N/A
Remarks: _____ Page 3

Illustrative Example Supplemental Notes

The strategies have been formulated and numbered, and the sources numbered. At this point, the user begins the iterative evaluation of initial alternatives for the various strategies and sources defined above, using: Figure 6-6 as a guide, Item 1ii (page 5) for keeping track of strategies and sources considered, and Item 2 (page 7) to record Present-Worth costs and information reliability for the various control alternatives considered.

By _____ Date _____ Strategy No. N/A
Checked by _____ Date _____ Source No. N/A
Remarks: _____ Page 4

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TABLE 6-3 (continued)
FRAMEWORK METHODOLOGY
WORKSHEET

Item 1 (continued)

ii. Record of load reduction strategies and sources considered.

- Check (x) the sources to be considered under each load-reduction strategy.
- Circle the checks in the matrix after all appropriate control alternatives have been considered for a source.
- Go to next load reduction strategy when all sources have been considered for that strategy.
- End when all strategies have been considered.

Load Reduction Strategy	Source Number					
	1	2	3	4	5	6
1a	x	x				
1b	x	x				
1c	x	x				
1d	x	x				
2a	x	x		x		
2b	x	x	x	x		
2c	x	x		x		
3a			x	x		
3b			x	x		
4			x			
5a	x	x				
5b	x	x				
6	x	x	x	x		
7	x	x	x	x		
8	x	x	x	x		
9	(x)	(x)	(x)	(x)		

By _____ Date _____ Strategy No. N/A
Checked by _____ Date _____ Source No. N/A
Remarks: _____ Page 5

Illustrative Example Supplemental Notes

For the illustrative example, Strategy 9 will be evaluated. This strategy has been selected because it requires use of all component methodologies. Actually Strategy 9 is a combination of a number of less comprehensive strategies (See Table 6-1). Since the example considers only Strategy 9, only sources for that strategy are circled in Item 1ii as a record of evaluation. In an actual case, all x's would be circled since all sources for all strategies would be considered.

By _____ Date _____ Strategy No. N/A

Checked by _____ Date _____ Source No. N/A

Remarks: _____ Page 6

TABLE 6-3 (continued)
FRAMEWORK METHODOLOGY
WORKSHEET

Item 2 - Feasible Control Alternatives.

i. Record the Present-Worth cost of control alternatives determined using the component methodologies.

ii. Record the worksheet page number (from lower right corner) where the present worth is recorded in the appropriate component methodology.

iii. Record the relative reliability of the performance and cost information for the control alternative as identified in Appendixes G and H or at the discretion of the user.

Load Reduction Strategy	Source	Control Alternative	Present-Worth $	Page	Information Reliability Performance	Cost
1a 8		Would be evaluated by user in an actual case. Illustrative example considers only Strategy 9.				
9	1	Treatment Facility	$61,700,000	26	B	B
9	1	Land Application	$42,120,000	53	B	B
9	1	Wastewater Reuse	Cost not generated; see note, page 54			
9	1	Impact Area Modif.	Cost not generated; see note, page 66			
9	2	Treatment Facility	Cost not generated for these control alternatives since the operations are the same as for Source 1.			
9	2	Land Application				
9	2	Wastewater Reuse				
9	2	Impact Area Modif.				
9	1,2	Regionalization				
9	3	Land Management	Cost estimates not computed for this example.			
9	3	Ablation/Irr. Control				
9	3	Storage/Treatment	$2,734,000	119	C	C
9	3	Wastewater Reuse	Costs not generated since operations similar to those already presented.			
9	3	Impact Area Modif.				
9	4	All Control Alternatives				
9	3,4	Regionalization				

By _____ Date _____ Strategy No. N/A
Checked by _____ Date _____ Source No. N/A
Remarks: _____ Page 7

Illustrative Example Supplemental Notes

The treatment facility evaluation included in the next few worksheets considers a single-phase project utilizing the existing treatment facility. Alternatives (not evaluated) would be abandonment of the existing facility or a multi-phased project. A complete residuals disposal evaluation is included in this treatment facility upgrading, involving consideration of a new landfill site. Transportation of the treatment plant residual (sludge) is by truck. The Present-Worth cost of the upgrading project is determined.

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Checked by _____ Date _____ Source No. N/A
Remarks: _____ Page 8

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TABLE 6-4
TREATMENT FACILITY METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgments presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach available (or even as the preferred approach). However, any approaches used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other EPA, State, and local guidelines and regulations.

Item 1 - Program Implementation Schedule.

i. Planning Period: 20 years

ii. Construction phases: 1

Phase	Timing Year	to	Year	Flow Projection (mgd) Start	End	Design Flow (mgd)
1*	Present	to	20	9	17	9
2		to				
3		to				
4		to				
n		to				

*Existing facility not utilized at full capacity.

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Checked by _____ Date _____ Source No. 1
Remarks: _____ Page 9

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TABLE 6-4 (continued)
TREATMENT FACILITY METHODOLOGY
WORKSHEET

iii. Treatment Objectives.

Note: Dissolved oxygen deficits use ultimate oxygen demand inputs (Table 6-3). These must be reconverted back to CBOD and NBOD (NH_3) concentrations to determine discharge limitations (See Appendix H discussion of Treatment Systems Performance Matrix).

	Effluent Quality								
Phase	Reference Cost Curve**	BOD mg/l	COD mg/l	TSS mg/l	T-P mg/l	NH_3-N mg/l	NO_3-N mg/l	T-N mg/l	T-C #/100ml
Existing Facility	H-2	130	250	100	9	20	0	20	—
1	H-12/S-1				2[a]			8[a]	
2	(see note, page 11)								
3									
n									

**Treatment System curve number (Appendix H, Figures H-2 to H-15) or reference number for synthesized system cost curve developed from unit process curves (Appendix H).

iv. Existing Facility Characteristics.

Design Capacity: 9 mgd

Service Life: 34 years

Years in Service: 20 years

Remaining Service: 14 years

Note:

[a] These parameters are the most critical and, therefore, define the required treatment level

By _____ Date _____ Strategy No. 9

Checked by _____ Date _____ Source No. 1

Remarks: Strategy to expand/upgrade existing facility Page 10

Illustrative Example Supplemental Notes

The required treatment level suggests that Treatment System H-12 could be used. However, for purposes of this example, it is assumed that local conditions require that an alternate system be used. Therefore a treatment system is synthesized using some of the unit process curves in Appendix H and some hypothetical "local cost estimates". This synthesized system, referred to as S-1, will provide the required treatment level. System units and construction and O & M costs are summarized, in the table below:

Synthesized System Cost Estimate

Treatment System Units	App H Curve No.	Construction Cost (10^6 $)	O&M Cost	Service Life
Wastewater Treatment:				
Lift Pumps	H-30	1.10	32,000	15
Preliminary Treatment	H-31	0.27	38,000	30
Primary Clarifier	Local Cost Est.	2.4	73,000	50
Act. Sludge	H-34	2.30	160,000	40
Second. Clar.	Local Cost Est.	2.3	120,000	30
Nitrification	Local Cost Est.	3.6	200,000	40
Denitrification	Local Cost Est.	2.5	600,000	30
Two Stage Lime	H-53	2.10	400,000	40
Filtration	H-56	2.00	170,000	30
Disinfection	H-58	0.28	87,000	15
Biological Sludge:				
Gravity Thick.	H-64	0.15	6,000	50
Anaerobic Digester	H-73	0.90	100,000	50
Vacuum Filt.	Local Cost Est.	1.15	200,000	20
Chemical Sludge:				
Gravity Thick.	H-64	0.15	6,000	50
Vacuum Filt.	Local Cost Est.	1.45	400,000	20
Misc. Structures	H-29	0.35	8,000	50
Support Personnel	H-28	-	100,000	-
TOTAL		23.00	2,700,000	

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TABLE 6-4 (CONTINUED)
TREATMENT FACILITY METHODOLOGY
WORKSHEET

Item 2 - Existing Facility Cost.
Note: For the first phase of new facility construction, Items 2i, 2ii, and 2iii will equal zero since there is no existing facility.

i. Capital Value (i.e., construction cost plus add-ons).

a. Design Q = 9 mgd

b. Level of Treatment: Reference Cost Curve H-2
Service Life 34 years

c.	Construction Cost (Curve $)	= $2,600,000
d.	plus Piping - Curve $ x 15%	= 390,000
	Electrical - Curve $ x 12%	= 312,000
	Instrumentation - Curve $ x 8%	= 208,000
	Site Preparation - Curve $ x 5%	= 130,000
	Miscellaneous Structures (None)	= 0
e.	Sub-Total 1, Construction Cost (c+d)	$3,640,000
f.	plus Sub-Total 1 x Engineering and Construction 15%	= 546,000
	Sub-Total 1 x Contingencies 15%	= 546,000
g.	Sub-Total 2: Capital Cost (e+f)	$4,732,000
h.	CAPITAL VALUE OF EXISTING FACILITY = Sub-Total 2 x ENR (Current) / 2475*	= $4,780,000

2499

* ENR = 2475, September, 1976.

ii. Replacement Cost.
(compute only if planning period is greater than remaining service life)

Replacement Cost = (Planning Period - Remaining Service Life) / Planning Period x Capital Value

$\frac{20-N}{20}$ x 4,780,000 = $1,430,000 at year 14

iii. Salvage Value. Service life @ 14 years is less than 20 years to planning period end.
(compute only if remaining service life is greater than planning period)

Salvage Value = (Remaining Service - Years to Planning End) / Remaining Service x Capital Value

= None at end of planning period.

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Remarks: _____ Page 12

TABLE 6-4 (CONTINUED)
TREATMENT FACILITY METHODOLOGY
WORKSHEET

Item 3 - Expansion Program or New Facility Construction.

Phase Number 1

i. Existing Capacity = 9 mgd (previous phase or existing facility; zero if new facility)

ii. Expanded or New Facility Capacity = 17 mgd (design capacity of next phase)

iii. Level of Treatment: Reference Cost Curve H-2
Service Life 34 years
(This is the treatment level of existing facility)

iv. Construction cost of expanded or new facility - enter cost curve at expanded or new facility at capacity (ii) 17 mgd — $4,000,000

v. Construction cost of existing facility - enter cost curve at existing facility at capacity (i) 9 mgd — 2,600,000

vi. Sub-Total 1: Expanded or New Facility Construction Cost (iv-v) = $1,400,000

vii. plus Sub-Total 1 x Piping 15% = 210,000
Sub-Total 1 x Electrical 12% = 168,000
Sub-Total 1 x Instrumentation 8% = 112,000
Sub-Total 1 x Site Preparation 5% = 70,000

viii. Sub-Total 2: Construction Cost (vi + vii) = $1,960,000

ix. plus Sub-Total 2 x Expansion/Upgrading Factor 5%(1) = 98,000
Sub-Total 2 x Engineering and Construction 15% = 294,000
Sub-Total 2 x Contingencies 15% = 294,000

x. Sub-Total 3: Capital Cost (viii + ix) = $2,646,000

xi. CAPITAL COST OF EXPANSION OR OF NEW FACILITY = Sub-Total 3 x ENR (Current) 2499 / 2475* = $2,670,000

* ENR (Engineering News Record) = 2475, September, 1976.

(1) Expansion/upgrading factor taken from Figure H-1 by entering the curve at 17 mgd.

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Remarks: _____ Page 13

TABLE 6-4 (CONTINUED)
TREATMENT FACILITY METHODOLOGY
WORKSHEET

Item 4 - Upgrading Program.

Phase Number 1

i.	Existing Level of Treatment: Reference Cost Curve (previous phase or existing facility)	H-2
ii.	Required Level of Treatment: Reference Cost Curve (for the identified phase)	S-1
	Service Life	35 years (1)
iii.	Q = 17 mgd (design capacity)	
iv.	Construction Cost at required level of treatment - curve from ii	$ 23,000,000
v.	Construction Cost at existing level of treatment - curve from i	4,000,000
vi.	Sub-Total 1: Construction Cost of Upgrading (iv-v)	= $ 19,000,000
vii.	plus Sub-Total 1 x Piping 15%	= 2,850,000
	Sub-Total 1 x Electrical 12%	= 2,280,000
	Sub-Total 1 x Instrumentation 8%	= 1,520,000
	Sub-Total 1 x Site Preparation 5%	= 950,000
viii.	Sub-Total 2: Construction Cost (vi + vii)	$ 26,600,000
ix.	plus Sub-Total 2 x Expansion/Upgrading Factor 5% (2)	= 1,330,000
	Sub-Total 2 x Engineering and Construction 15%	= 3,990,000
	Sub-Total 2 x Contingencies 15%	= 3,990,000
x.	Sub-Total 3: Capital Cost (viii + ix)	$ 35,910,000
xi.	CAPITAL COST OF UPGRADING = Sub-Total 3 x $\frac{\text{ENR (Current)}}{2475^*}$ ($\frac{2449}{2475^*}$)	= $ 36,300,000

* ENR = 2475, September, 1976.

(1) Composite service life. Average of service lives of individual units weighted by construction costs.

(2) Expansion/upgrading factor is from Figure H-1 by entering at the flow rate of 17 mgd.

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TABLE 6-4 (CONTINUED)
TREATMENT FACILITY METHODOLOGY
WORKSHEET

Item 5 - O&M Constant and Variable Cost.

Note: this level is used to identify O&M cost since it represents the actual treatment level.

Phase 1

Level of Treatment: Reference Cost Curve S-1

Timing Start (yr.)	Timing End (yr.)	Design Flow Start (mgd)	Design Flow End (mgd)	O&M Cost Start	O&M Cost End
1	20	9	17	$1,600,000*	$2,700,000

*Developed similarly to S-1 cost estimate at 17 mgd on page 11.

Item 6 - Phase 1 Replacement Costs (Upgraded and/or Expanded Portion) (Compute if planning period is greater than phase service life) Replacement Cost Schedule.

There are no replacement costs for this phase.

Expansion Year	Expansion Cost	Upgrading Year	Upgrading Cost	Total Year	Total Cost
None		None		None	

Replacement Cost for Phase 1 =

$$\frac{\text{Years from Time of Replacement to end of Planning Period}}{\text{Service Life}} \times \text{Capital}$$

Note: the replacement cost for the existing facility has been estimated in Item 2.

Item 7 - Phase 1 Salvage Value at End of Planning Period. (Compute if phase service life is greater than years to planning period end)

$$\text{Salvage Value} = \frac{\text{(Service Life - Years to Planning End)}}{\text{Service Life}} \times \text{Capital}$$

Expansion S.V. = $\frac{34 - 20}{34} \times 2{,}670{,}000$ $1,100,000

Upgrading S.V. = $\frac{35 - 20}{35} \times 36{,}300{,}000$ $15,600,000

Total Phase S.V. $16,700,000

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Illustrative Example Supplemental Notes

For a more complex problem, there would probably be more than one phase for evaluation. If so, the sheets with Items 3, 4, 5, 6, and 7 would be repeated at this point in the evaluation, once for each project phase.

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Remarks: _____ Page 16

TABLE 6-4 (CONTINUED)
TREATMENT FACILITY METHODOLOGY
WORKSHEET

Item 8 - Residual Disposal Cost, using RESIDUALS DISPOSAL METHODOLOGY.

i. Residual Disposal Technique.

Solids Nature dewatered solids (20%, 30%)

Residual Type biological, chemical

Disposal Method landfill

Transportation Truck

ii. Residual Disposal Cost Schedule.

Phase	Timing Yr. to Yr.		Capital	O&M Start	O&M End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Land Cost[1]	1	20	184,000					184,000
1 Bio[2]	1	20	248,000	130,000	140,000	15	43,000	0
1 Chem[2]	1	20	652,000	240,000	290,000	15	117,000	0
3								
n								
Total			1,084,000	370,000	430,000	15	160,000	184,000

Notes:

1. The cost for land is taken from Residuals Disposal, Item 3 iii (page 21).
2. The cost for Phase 1 (Bio + Chem) is the sum of the landfill site and truck costs taken from Item 3 iii (page 21) and Item 5 iii (page 23).

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Illustrative Example Supplemental Notes

Pages 19-26 are worksheets for the RESIDUALS DISPOSAL METHODOLOGY, which is another component methodology utilized by the TREATMENT FACILITY METHODOLOGY to make a specific determination, the cost of residuals disposal. The use of component methodologies in this fashion will occur throughout the example. See Table 6-20 for an overview of which component methodologies are utilized in evaluating control alternatives for the various sources.

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TABLE 6-17 (continued)
RESIDUALS DISPOSAL METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgments presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach available (or even as the preferred approach). However, any approaches used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other EPA, State, and local guidelines and regulations.

Item 1 - Residual Characteristics.

i. Residual generator method of treatment:
Primary clarification, activated sludge, nitrification, denitrification, two-stage lime

ii. Residual description: Biological and chemical (lime)

iii. Feasible disposal techniques: Landfill

IV. Residual quantity: (ultimate)

Design Year Flow Rate 17 mgd

Residual Generation 900(bio)+6,300(chem) lb/mgd (dry basis) (Note 3)

Disposal Quantity 122,400 lb/day (dry basis)
(7200 x 17 mgd)

Item 2 - Residual Disposal Sites.

i. Site characteristics summary.

	Site	Location	Distance from Generator	Estimated Useful Capacity	Comments
a) Existing Land Spreading Sites.		Not Applicable			
b) Existing Landfill Sites.	1	SDI Facility	0 miles	0.12yr (a)	Site inadequate for future use.
c) Potential Sites.					
i) Landfill.	2	off Hwy 3 east of SDI	10 miles	Uncertain (200 acres)	Site recently cleared.
ii) Land Spreading.		Not Applicable			

(a) Determined on page 20, Item 2 ii.

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Remarks: These calculation sheets (pages 18-25) develop cost schedule for page 17 of TREATMENT FACILITY METHODOLOGY. Page 19

TABLE 6-17 (continued)
RESIDUALS DISPOSAL METHODOLOGY
WORKSHEET

Item 2 - continued

iii. Site capacity evaluation - existing site #1

a) Useful life at existing disposal rate: 2 years

b) Existing disposal rate: *(615 lb/mg)(9 mgd) = 5,500 lb/day or ton/day or cu yd/day

c) Proposed disposal rate: 93,600' lbs/day (same units as above)

(use average rate for entire planning period)

d) Useful life at proposed disposal rate = (a) x $\frac{(b)}{(c)}$ = 0.1 yr[2]

* Primary treatment (assumed for illustrative purposes)

Note:

1 Average proposed disposal rate =

$$= \left(\frac{9\ mgd + 17\ mgd}{2}\right)\left(\frac{122{,}400\ lb/day}{17\ mgd}\right) =$$

$$= 93{,}600$$

2 Useful life = $2\ yr \times \frac{5{,}500\ lb/day}{93{,}600\ lb/day} = 0.12\ yr$

The user should refer to sludge handling curves (H-64 — H-72) appropriate to treatment process. In this example, biological sludge is processed by an aerobic digester (H-73), and chemical sludge is processed by a vacuum filter (local cost estimate; residuals generation rate comparable to other chemical sludge processes.

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TABLE 6-17
RESIDUALS DISPOSAL METHODOLOGY
WORKSHEET

Item 3 - Cost for Development of Residual Disposal Site.

i. Program Schedule.

Phase	Timing Yr to Yr		Design Flows (mgd) Start	End
1	1	to 20	9	17
2		to		
3		to		
n		to		

ii. Site Development Schedule.

Phase	Design Flow (mgd)	Land Required[1] (acre)	Land Cost[2]
1	17	92 (19 bio/73 chem)	184,000
2			
3			
n			

[1]Land Required = 1.1(bio) + 4.3(chem) acre/mgd

[2]Land Cost = $ 2,000 /acre

Note: From cost curve information in Appendix H (Figures H-81 and H-82)

iii. Project Cost Schedule - Disposal Site.

Phase	Timing Yr	to Yr	Capital[1]	O&M Start	O&M End	Replacement Cost[2] Year	Replacement Cost[2] Cost	Salvage Value[2]
Land Cost	1	20	184,000	N/A	N/A	N/A	N/A	184,000
1 Bio	1	20	118,000	30,000	40,000	None		0
1 chem	1	20	302,000	70,000	120,000	None		0
3								
n								

[1]Capital computed as described for TREATMENT FACILITY METHODOLOGY; includes construction add on's to reflect installed capital. Capital = curve $ x (1.0 + Construction Add on's.)

[2]Cost computed as described for TREATMENT FACILITY METHODOLOGY; attach appropriate computations.

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Remarks: Reference page 22 for capital (item iii) estimate. Page 21

Supplemental Calculations: Residuals Disposal

Item 3 iiii

Biological Landfill: (Service Life = 20 years)

Flow = 17 mgd
Curve $ = 90,000
Add O/M's:
Engineering/Const. (15%) = 13,500
Contingency (15%) = 13,500
Sub 2 $117,000

$ENR = \frac{2499}{2475} \times$ Sub 2

Construction = $118,000

No phase out cost
No salvage value
No replacement cost
} Both landfills

Chemical Landfill: (Service Life = 20 years)

Flow = 17 mgd
Curve $ = 230,000
Add O/M's:
Engineering/Const (15%) = 34,500
Contingency (15%) = 34,500
Sub 2 $299,000

$ENR = \frac{2499}{2475} \times$ Sub 2

Capital = $302,000

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TABLE 6-17 (continued)
RESIDUALS DISPOSAL METHODOLOGY
WORKSHEET

Item 4 - Residual Disposal Cost for Existing Site.

Phase	Timing Yr to Yr	Program Costs: Design Flow (mgd) Start	End	Residual Quantity[1] Start	End	Disposal Cost[2] Start	End
1	This is not applicable for this evaluation because an existing site is not being considered.						
2							
3							
n							

[1]Determined using _____ lb/mg

[2]Determined using ($_____/lb disposal cost) x (Residual Quantity lb/yr)

Item 5 - Residual Transportation Cost (using appropriate cost curves in Appendix H, Figures H-86 to H-90, or equivalent.

i. Transportation Method: truck

Residual Characteristics: Type Bio / chem Solids 20% / 30%

ii. Transportation Cost Schedule. Bio sludge is 900/7200 = 13% total; chem = 87%

Phase	Timing Yr to Yr		Capital[1]	O&M Start	O&M End	Design Flow Start	Design Flow End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Bio 1	1	20	130,000	100,000	100,000	*	*	15	43,000	0
chem 1	1	20	350,000	170,000	170,000	*	*	15	117,000	0
3										
n										

* Average condition was used for simplicity. See page 24.

[1]Develop capital estimate based on end design flow for each phase; include construction add on's to reflect installed cost.

[2]Develop O&M estimate (start and end) for each phase.

a O & M costs are adjusted for haul distance as described in supplemental calculations.

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Supplemental Calculations: Residual Disposal

Item 5 i i

1) It is assumed that biological sludge at 20% solids has 340 lb solids/cu yd, and a chemical sludge has 500 lb solids/cu yd at 30%.
2) The biological sludge represents $\frac{900}{900+6300}$ = 13% of the residual, with the chemical sludge at 87%.
3) Capital cost will be developed for an average residual quantity, defined on calculation page 20 (note 1) to be 93,600 lb/day.
4) O&M cost (for simplicity) will also be calculated for this average quantity.

Biological Residual

Quantity/day = (93,600 lb/day)(0.13)$\left(\frac{1}{340 \text{ lb/cu yd}}\right)$ = 36 cu yd/day

Capital cost = $130,000 year 1, service life 15 years.
Therefore, Replacement Cost = $\left(\frac{20-15}{15}\right)$(130,000) = $43,000 at year 15.

O&M (start) = $100,000 = end O&M

Chemical Residual

Quantity/day = (93,600)(0.87)$\left(\frac{1}{500}\right)$ = 163 cu yd/day

Capital cost = $350,000 year 1, service life 15 years.

Replacement Cost = $\left(\frac{20-15}{15}\right)$(350,000) = $117,000 at year 15.

O&M (start) = $170,000 = O&M (end)

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TABLE 6-17 (continued)
RESIDUALS DISPOSAL METHODOLOGY
WORKSHEET

Item 6 - Residual Disposal Site Present-Worth Cost

i. Alternative Characteristics:

Residual — This section is not completed for this evaluation because only one residual disposal scheme is under consideration.

Solids

Transportation Method

Disposal Method

ii. Present-Worth Cost (from PRESENT-WORTH METHODOLOGY) $ _____

Reference Sheets _____

Item 7 - Site Alternatives Summary - Residuals Disposal

Site	Location	Present-Worth Cost

This schedule is not completed for the illustrative example because only one residual site is under consideration.

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TABLE 6-4 (CONTINUED)
TREATMENT FACILITY METHODOLOGY
WORKSHEET

Item 9 - Project Cost Schedule (Summary of costs developed in TREATMENT FACILITY METHODOLOGY).

Phase	Year to Year	Item No.	Capital Cost	Start O&M	End O&M	Variable O&M	Salvage Value
1	1 to 20	3 (Expand/New)	2,670,000	-	-	-	-
		4 (Upgrade	36,300,000	-	-	-	-
		5/6/7	-	1,600,000	2,700,000	-	16,700,000
		8 (Residual)	1,084,000	370,000	430,000	-	184,000
	Total Phase 1		40,050,000	1,970,000	3,130,000	$8,000	16,900,000
2		3 (Expand/New)	Phase 1 Variable O&M = $\frac{3,130,000 - 1,970,000}{20}$				
		4 (Upgrade)					
		5/6/7					
		8 (Residuals)					
	Total Phase 2						
3		3 (Expand/New)					
		4 Upgrade)					
		5/6/7					
		8 (Residuals)					
	Total Phase 3						
n		3 (Expand/New)					
		4 (Upgrade)					
		5/6/7					
		8 (Residuals)					
	Total Phase n						

Replacement Schedule

Year	Cost
14	1,430,000
15	160,000

The year 14 cost is from page 12 of these calculations; year 15 cost is from page 23.

Item 10 - Present-Worth Cost, using PRESENT-WORTH METHODOLOGY

Interest 7 % (from Water Resources Council 18 CFR 704.39, Discount Rate, published annually)

Present-Worth Cost $ 61,700,000

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Remarks: This sheet returns to TREATMENT FACILITY METHODOLOGY Page 26

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TABLE 6-16
PRESENT-WORTH METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgements presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach available (or even as the preferred approach). However, any approaches used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other EPA, State, and local guidelines and regulations.

Items 1-10 Present-Worth Calculation.

Planning Period 20 years Interest 7 %

	Item (Reference Page)	Amount		Present-Worth
1.	Phase 1 Capital (pg. 26)	40,050,000	x 1.0 (Yr 1)	40,050,000
2.	Phase 2 Capital (pg. ___)	_____	x _____ ($sppwf^a$) (Yr ___)	_____
3.	Phase 3 Capital (pg. ___)	_____	x _____ ($sppwf^b$) (Yr ___)	_____
4.	Phase n Capital (pg. ___)	_____	x _____ ($sppwf^c$) (Yr ___)	_____
5.	Replacement year (h) (pg. 26)	1,430,000	x 0.39 ($sppwf^h$) (Yr 14)	560,000
6.	Replacement year (i) (pg. 26)	160,000	x 0.36 ($sppwf^i$) (Yr 15)	58,000
7.	Replacement year (j) (pg. ___)	_____	x _____ ($sppwf^j$) (Yr ___)	_____
8.	Replacement year (k) (pg. ___)	_____	x _____ ($sppwf^k$) (Yr ___)	_____
9.	Replacement year (l) (pg. ___)	_____	x _____ ($sppwf^l$) (Yr ___)	_____
10.	Salvage Value (Negative Cost) (pg. 26)	(-16,900,000)	x 0.26 ($sppwf^z$) (Yr 20)	(-4,390,000

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Remarks: These sheets develop present worth costs for TREATMENT FACILITY METHODOLOGY Page 27

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TABLE 6-16 (continued)
PRESENT-WORTH METHODOLOGY
WORKSHEET

Item 11 - 19 Present-Worth Calculation.

Planning Period 20 years Interest 7 %

	Item (Reference Page)	Amount		Present-Worth
11.	O&M Phase 1 Constant (pg. 26)	1,970,000	x 10.6 (uspwf[d]) x 1.0 (#Yrs 20 ; Yr 1)	20,880,000
12.	O&M Phase 1 Variable (pg. 26)	$8,000	x 77.5 (gspwf[d]) x 1.0 (#Yrs 20 ; Yr 1)	4,495,000
13.	O&M Phase 2 Constant (pg. ___)	_____	x ____ (uspwf[e] x sppwf[a]) (#Yrs____ ; Yr____)	_____
14.	O&M Phase 2 Variable (pg. ___)	_____	x ____ (gspwf[e] x sppwf[a]) (#Yrs____ ; Yr____)	_____
15.	O&M Phase 3 Constant (pg. ___)	_____	x ____ (uspwf[f] x sppwf[b]) (#Yrs____ ; Yr____)	_____
16.	O&M Phase 3 Variable (pg. ___)	_____	x ____ (gspwf[f] x sppwf[b]) (#Yrs____ ; Yr____)	_____
17.	O&M Phase n Constant (pg.___)	_____	x ____ (uspwf[g] x sppwf[c]) (#Yrs____ ; Yr____)	_____
18.	O&M Phase n Variable (pg.___)	_____	x ____ (gspwf[g] x sppwf[c]) (#Yrs____ ; Yr___)	_____
19.			TOTAL PRESENT-WORTH	$ 61,700,000

Reference

a) Principles of Engineering Economy, Grant and Ireson, 5th Edition, 1970. sppwf[b], sppwf[a], sppwf[e], uspwf[d]

b) Principles and Problems Engineering Economics, U.S. Army Engineering School, Fort Belvoir, VA, 15 March 1969. gspwf[d]

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Illustrative Example Supplemental Notes

The next evaluation for Source 1, as indicated by the flowchart Figure 6-6, is land application of the wastewater. A complete evaluation of an undrained application site is included in the attached worksheets. Also included is a complete cost determination for the wastewater transportation pipeline from the existing treatment facility site to the application site. The Present-Worth calculations are also included.

An underdrained system could also be evaluated using these worksheets. In this case there would still be a discharge to the receiving water.

The pipeline route evaluated for this example includes force main and gravity segments and the associated pumping costs. Only one route is evaluated, but if another route were to be considered, the user could determine the Present-Worth cost for each.

The Present-Worth analysis included in this example includes all expected construction expenditures and operation and maintenance items. Salvage values at the end of the project life and replacement costs for equipment are included. Finally, a negative cost is identified to reflect assumed revenues from the land application site for marketable crops.

The land application site evaluated for this example was an undrained site; thus, there would be no direct discharge of wastewater from Source 1 to the receiving stream. Therefore, the original load-reduction strategy, which was based on a discharge from Source 1 and Source 2, could likely be modified to allow less treatment at Source 2.

In an actual case similar to this situation, the user would utilize the water quality impact analysis techniques presented in Chapter 5 to reevaluate the waste load allocations for use in evaluating control alternatives for the

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Illustrative Example Supplemental Notes (continued)

other sources if undrained land application were to be the selected alternative for the source under consideration. Of course, for control alternatives other than undrained land application for Source 1, the original load allocations for all sources would again be used.

For this example, the original load allocations will be used throughout since the techniques are the same and, thus, serve for illustration.

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TABLE 6-5 (CONTINUED)
LAND APPLICATION METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgments presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach available (or even as the preferred approach). However, any approach used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other EPA, State, and local guidelines and regulations.

PROJECT SCHEDULE

Item 1 - Program Implementation Schedule.

i. Planning Period: 20 years

ii. Existing Facility Conditions. Treatment Facility

Design Capacity:	9	mgd
Years of Service:	20	years
Remaining Service:	14	years

iii. Treatment Levels.

Note: Dissolved oxygen deficits use ultimate oxygen demand inputs (Table 6-3). These must be reconverted back to CBOD and NBOD (NH_3) concentrations in order to determine discharge limitations (See Appendix H discussion of Treatment Systems Performance Ratios).

Level	Reference Cost Curve	Parameter Control Levels BOD mg/l	COD mg/l	TSS mg/l	T-P mg/l	NH_3-N mg/l	NO_3-N mg/l	T-N mg/l	T-C #/100ml
Existing Facility	H-2	130	250	100	9	20	0	20	—
Pretreatment	H-6(1)	20	-	20	7	17			
Discharge Limitations	H-12/S-1	(See Note page 11)			2			8	

iv. Construction Phases: 1

(1) This is considered to be the minimum acceptable treatment level (only for this example).

Phase	Timing Year to Year	Design Flow (mgd) Flow Projection Start	Flow Projection End	Pretreatment Start	Pretreatment End	Transportation	Site Start	Site End
1	1 - 20	9	17	9	17	17	9	17
2								
3								
n								

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TABLE 6-5 (CONTINUED)
LAND APPLICATION METHODOLOGY
WORKSHEET

GENERAL SITE EVALUATION

Item 2 - Land Application Ultimate Area Requirement.

i. Maximum Annual Flow Rate at end of Planning Period = 17 mgd

ii. Application Rate[1] = 2.5 in./week (Based on general application rates in the area)

iii. Non-operating time = 13 weeks/year

iv. Area Required = 2,800 acres, without buffer zone (includes area for roads, buildings, etc.)

Gross Area Required (with 200 ft buffer zone)[2] = 3,100 acres

(Use Nomograph "Total Land Requirement", Figure 6-13, or equivalent)

[1] Items 2ii and 2iii can be used for determining maximum capacity for potential LA sites in Item 5.

[2] Use a more stringent buffer zone limitation if indicated by applicable Federal, State, or local regulations or site conditions.

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TABLE 6-5 (CONTINUED)
LAND APPLICATION METHODOLOGY
WORKSHEET

Item 3 - Potential LA Sites - Location.

(Attach USGS Quad Sheet or equivalent with potential sites outlined and identified.)

Attached is Figure 2-5 upon which is outlined the location of three potential LA sites. This sheet can be used to approximate distances to the three sites from the treatment systems.

A USGS Quad Sheet or other suitable map would be preferred since it would give more reliable information concerning the existing land use at these specific sites.

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Remarks: Referenced figures are in Chapter 2 of this manual. Page 33

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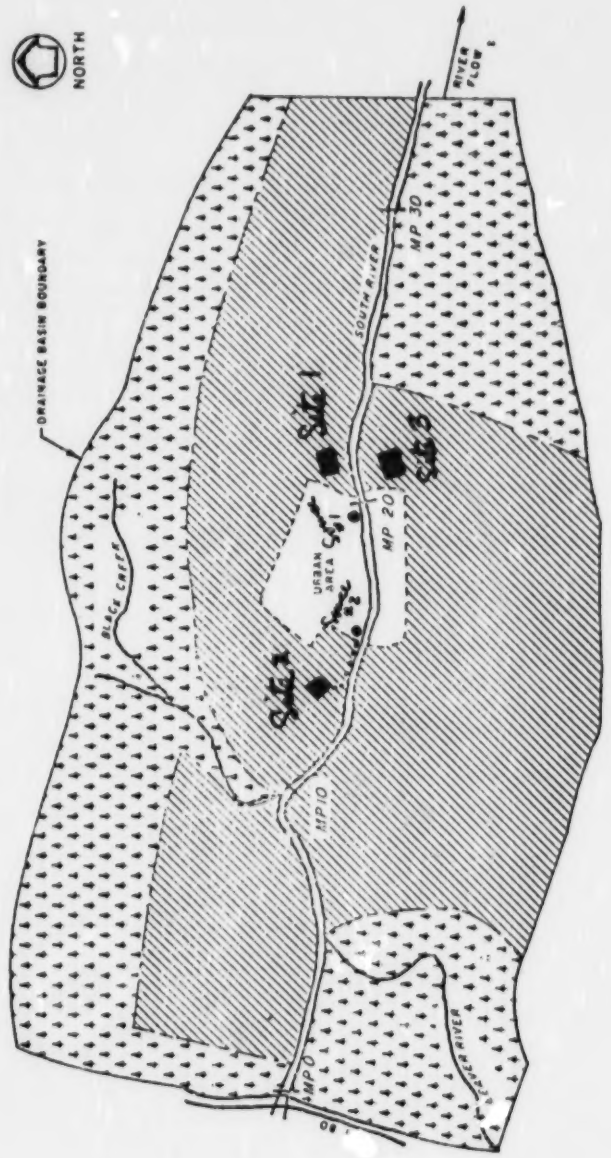

FIGURE 2-5
SIMPLIFIED LAND USE PATTERNS
(SOUTH RIVER, U.S.A.)
HYPOTHETICAL EXAMPLE

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TABLE 6-5

LAND APPLICATION METHODOLOGY
WORKSHEET

Item 4 - Potential LA Sites Data Sheet. (Sample of factors to be considered. This is not an inclusive list; see LA references for additional considerations.)

Site	Approximate Available area (acres)	Estimated treatment capacity (mgd)	Area of site presently irrigated (percent)	Distance from plant (feet)	Elevation difference from plant (feet)	Homes onsite (No.)	Other buildings onsite (No.)	Roads onsite (miles)	Comments-Major problems or advantages
1	3,500	17.5	0	6,900	185	4	5	3.7	1) close to river 2) land for subsurface from boulder
2	7,000	37	0	28,000	320	5	2	4.9	1) pumping required 2) close to river; boulder 3) portions of site may not be suitable
3	12,000	73	0	7,950	100	8	13	8.3	1) close to river; potential boulder 2) access road required; may cross drainage 3) potential regional site for SD 1&2

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TABLE 6-5 (CONTINUED)
LAND APPLICATION METHODOLOGY
WORKSHEET

SPECIFIC SITE EVALUATION
SITE 1

Item 5 - Site Implementation Schedule.

i. Planning Period: 20 years

ii. Construction Phases: 1
(If different from Project Schedule, then describe.)

iii. Pretreatment Requirements: Reference Cost Curve H-6
(If different from Project Schedule, then describe.)

iv. Performance Characteristics - existing facility: Reference Cost Curve H-2 (From Item 1iii)

Item 6 - Pre-application Treatment Cost.

i. Use Treatment Facility Methodology.

Phase	Timing Yr. to Yr.		Capital	O&M Start	O&M End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Existing Facility	Note: This information would be entered from the worksheets							
1	for TREATMENT FACILITY METHODOLOGY, TABLE 6-4; that							
2	methodology has been used in a previous portion of this							
3	Illustrative Example.							
n								

Item 7 - Land Cost. Note: This schedule will not be used because the cost curve in Figure H-16 (Land Application of Wastewater) includes land cost at $1,000/acre which is adequate for this example.

Application Rate = _____ in./week
Curve Rate = _____ in./week
Factor = Application Rate/Curve Rate = _____

Phase	Design[1] Flow	Adjusted[2] Flow	Land Cost	Salvage Value
1				
2				
3				
n				

[1]Design Flow is the desired application site daily capacity addition for the project Phase.
[2]Adjusted Flow = Design Flow x Factor

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TABLE 6-5 (CONTINUED)
LAND APPLICATION METHODOLOGY
WORKSHEET

Item 8 - Transportation Cost.

i. Use Table 6-18, TRANSPORTATION COST METHODOLOGY to complete following schedule:

Phase	Capital	O&M Start	O&M End	Salvage Value
1	3,564,000	120,000	199,000	402,000
2				
3				
n				

Replacement Schedule

Year	Cost
15	1,000,000

Item 9 - Application Site Costs.

i. Use cost curve in Appendix H, Figure H-16, or equivalent method:
Curve No. H-16
Service Life 30 years

Phase	Timing Yr to Yr	Flow Rate, mgd Start	Flow Rate, mgd End	Design, mgd	Capital Cost	O&M Start	O&M End	Salvage[2] Value	Revenue[3] Start	Revenue[3] End
1	1 - 20	9	17	17	13,009,000	490,000	930,000	5,670,000	60,000	120,000
2										
3										
n										

Replacement Schedule

Year	Cost
None	

$\frac{30-20}{30}$ x Capital

[1]Adjust curve cost to reflect installed cost.
[2]Develop Salvage Value = $\frac{\text{Service Life - Years to Planning End}}{\text{Service Life}}$ x Capital
which reflects the remaining Phase value at the planning period end.
[3]Include crop revenues, etc.
Net Revenue Estimate: Start = $40/acre/yr
End = $50/acre/yr

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TABLE 6-18
TRANSPORTATION COST METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgments presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach available (or even as the preferred approach). However, any approaches used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other EPA, State, and local guidelines and regulations.

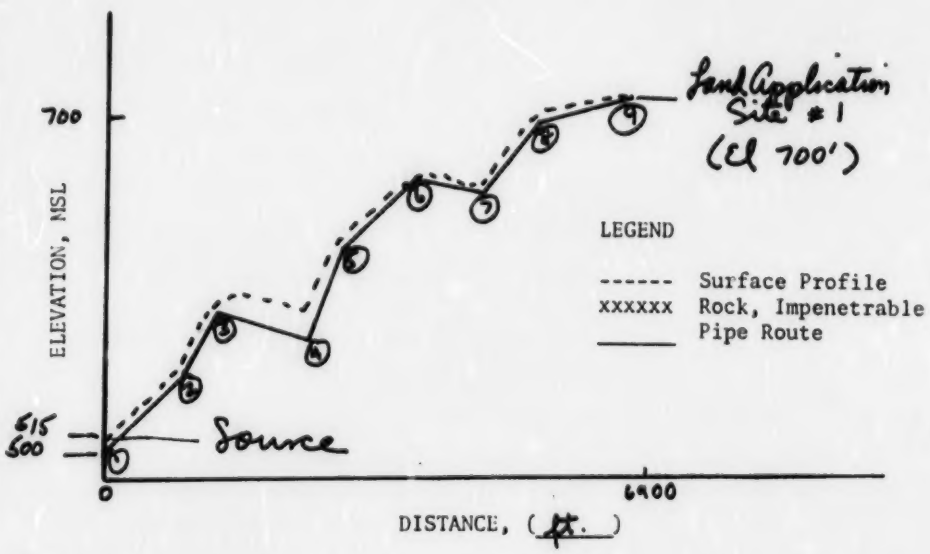
Item 1 - Project/Phase/Source Identification.

i. Project: Land Application

ii. Source Identification

Source	Elevation	Design Flow (mgd) @ Phase No.				
		1	2	3	n	Design Yr
Land Application Site #1	700' MSL					
Source	515' MSL	-	-	-	-	-

Item 2 - Transportation Route Profile.
(also locate route on topographic map)



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Remarks: These sheets (pages 38 & 47) develop transportation cost for LA page 37. Page 38

TABLE 6-18 (continued)
TRANSPORTATION COST METHODOLOGY
WORKSHEET

Item 3 - Critical Segments of the Transportation Route.

Flow Rate: 17 mgd (11.0 cfs) Assumed n-value: 0.015

	Segment	Elevation/Station[1] E/S(A)	to E/S(B)	Slope[2]	Velocity[3]	Flow Type[4]
a)	①-③	584	515	-0.05	-	FM
b)	③-④	572	584	+0.01	5.2 fps	G
c)	④-⑥	652	572	-0.06	-	FM
d)	⑥-⑦	660	652	+0.01	5.2 fps	G
	⑦-⑨	700	660	-0.02	-	FM

Notes:

1. Define Elevation Station Data from upstream E/S(A) to downstream E/S(B).

2. Slope = $\frac{E(B) - E(A)}{S(B) - S(A)}$ Units: ft/ft

3. Determine velocity only for positive slope condition; negative slope indicates force main (see discussion); use the attached nomograph (Hydraulic Computations).

4. Flow type: Gravity if positive slope and acceptable velocity (2 fps minimum); force main for other conditions.

Reference calculation sheets: None

Item 4 - Gravity Segments.

Flow Rate: 17 mgd

	Segment	Flow Rate (mgd)	Length (ft)
a)	3 - 4	17	1,100
b)	6 - 7	17	800
c)			
d)			
TOTAL			

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TABLE 6-18 (continued)
TRANSPORTATION COST METHODOLOGY
WORKSHEET

Item 5 - Force Main Segments.

	Segment	Length	Static Head[1]	Dynamic Head[2]	Pumping Head[3]
a)	①-③	1,400'	69'	14'	83'
b)	④-⑥	1,400'	80'	16'	96'
c)	⑦-⑨	2,200'	40'	8'	48'
d)					

Notes: [1]Static head = elevation difference from upstream to downstream.

[2]Dynamic head = See Discussion, Step 2 (Item 5).

[3]Pumping head = Static head + Dynamic head.

Reference calculation sheets: None

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TABLE 6-18 (continued)
TRANSPORTATION COST METHODOLOGY
WORKSHEET

COST DETERMINATION

Item 6 - Project/Phase Identification.

Project: Land Application

Phase: 1

Item 7 - Gravity Sewer Costs.

i. Reference Cost Curve: Figure II-84 (or equivalent curve)
Service Life: 50 years.
Gravity Sewer Length: 0.36 mile ~~feet~~
Design Flow Rate: 17 mgd

ii. Cost Determination.

Construction Cost: $ 154,000 [a]
(Compute only for Phases that include sewer construction; adjust curve cost to reflect installed cost.)

O&M Cost - Start: $ 500 [b]
O&M Cost - End: $ 500
Replacement Cost: None
Salvage Value (SV)[1] $ 92,000 [c]

$$^{1}SV = \frac{\text{(Service Life - Years to Project End)}}{\text{(Service Life)}} \times \text{Capital}$$

[a] Construction cost includes 30% of curve cost for Engineering, Construction Supervision, and Contingency

$$\text{Cost} = \left(\frac{330{,}000}{\text{mile}}\right)(0.36\ \text{mile})(1.0+0.3) = \$154{,}000$$

[b] $$O\&M = \left(\frac{1300}{\text{mile}}\right)(0.36) = 470 \approx 500$$

[c] $$SV = \frac{50-20}{50} \times 154{,}000 = 92{,}000$$

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TABLE 6-18 (continued)
TRANSPORTATION COST METHODOLOGY
WORKSHEET

Item 8 - Force Main Cost.

i. Phase: 1

Cost Curve: Figure H-85 (or equivalent curve)

Service Life: 50 years

Length: 5,000 ft

a) 0.95 miles @ 17 mgd

b) _____ ft @ _____ mgd

c) _____ ft @ _____ mgd

ii. Cost Determination.

	Segment a	Segment b	Segment c
Capital Cost[1]	410,000 [a]		
O&M Cost - Start	500 [b]		
O&M Cost - End	500		
Replacement Cost	None	None	None
Salvage Value (SV)[2]	310,000 [c]		

[1] Compute only for Phases that include force main construction; adjust curve cost to reflect installed cost.

[2] $SV = \frac{\text{(Service Life - Years to Project End)}}{\text{(Service Life)}} \times \text{Capital}$

a Cost $= \left(\frac{330,000}{\text{mile}}\right)(0.95)(1+0.3) = 410,000$

b O&M $= \left(\frac{\$500}{\text{mile}}\right)(0.95) = 480 \approx 500$

c $SV = \frac{50-20}{30} \times 410,000 = 310,000$

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TABLE 6-18 (continued)
TRANSPORTATION COST METHODOLOGY
WORKSHEET

Item 9 - Pump Station/Pumping Cost.

i. Phase: 1

Service Life: 15 years

Pumping Head/Flow: from page 40

	Segment	Total Head	Flow Rate Start	Flow Rate End
(a)	1 - 3	83'	9 mgd	17 mgd
(b)	4 - 6	76'	9 mgd	17 mgd
(c)	7 - 9	48'	9 mgd	17 mgd

ii. Cost Determination. (Cost curve Figure H-30, or equivalent)

Segment:	(a)	(b)	(c)
Capital Cost[1]	1,000,000	1,000,000	1,000,000
O&M Adjustment for head[2]	( )	( )	( )
O&M - Start[3]	44,000	42,000	33,000
O&M - End[3]	74,000	70,000	54,000
Replacement Cost/Year[4]	330,000/15	330,000/15	330,000/15
Salvage Value (SV)[5]	None	None	None

(Service life < years to project end)

Notes: [1]Compute only for Phases that include pumping capacity expansion; adjust curve cost to reflect installed cost.

see page 44

[2]Compute as described by the cost curve.

[3]O&M Cost = Curve Cost + Adjustment $\frac{20-15}{15} \times 1{,}000{,}000 = 330{,}000$

(4) Replacement Cost = $\frac{\text{Years Remaining in Project-Service Life}}{\text{Service Life}}$ x Capital

[5]SV = $\frac{\text{(Service Life - Years Remaining in Project)}}{\text{(Service Life)}}$ x Capital

If Salvage Value is negative, enter as 0 and compute replacement cost.

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Supplemental Calculation: Transportation

Item 9 ii

O&M adjustment for TDH other than 10'

Segment =	Start O&M			End O&M		
	a	b	c	a	b	c
Actual TDH	83'	76'	48'	83'	76'	48'
Q, actual, mgd	9	9	9	17	17	17
Q_e*, mgd	75	68	43	141	129	82
Power Cost @ Q_e	25,000	23,000	14,000	47,000	43,000	27,000
Labor @ Q	12,000	12,000	12,000	15,000	15,000	15,000
Material @ Q	7,000	7,000	7,000	12,000	12,000	12,000
TOTAL	44,000	42,000	33,000	74,000	70,000	54,000

Note:

1. Power cost for Q_e > 100 mgd made by extending the curve.
2. Q_e estimated by: $Q_e = Q_{design} \times \frac{TDH}{10}$

a) $Q_e = 17 \times 83/10 = 141$ mgd (end), 75 mgd (start)

b) $Q_e = 17 \times 76/10 = 129$ mgd (end), 68 mgd (start)

c) $Q_e = 17 \times 48/10 = 82$ mgd (end), 43 mgd (start)

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Illustrative Example Supplemental Notes

For certain projects, additional phases might be identified to consider the staging of pump stations, etc. The appropriate sheets (Items 6, 7, 8, and 9) would be included at this point.

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TABLE 6-18 (continued)
TRANSPORTATION COST METHODOLOGY
WORKSHEET

Item 10 - Transportation Cost Summary.

1. Cost Schedule.

Phase	Item	Capital Cost	Start - O&M	End - O&M	Salvage Value	
1	#7	154,000	500	500	92,000	Pg. 41
	#8	410,000	500	500	310,000	Pg. 42
	#9	3,000,000	119,000	198,000	None	Pg. 43
	TOTAL PHASE 1	3,564,000	120,000	199,000	402,000	
2	#7					
	#8					
	#9					
	TOTAL PHASE 2					
3	#7					
	#8					
	#9					
	TOTAL PHASE 3					
n	#7					
	#8					
	#9					
	TOTAL PHASE n					

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TABLE 6-18 (continued)
TRANSPORTATION COST METHODOLOGY
WORKSHEET

Item 10 - Transportation Cost Summary (continued).

Replacement Schedule		
Item	Year	Cost
9	15	1,000,000

ii. Present-Worth Cost: $ Not required. Cost schedule will be transferred to page 37 of the Land Application evaluation for Source 1.

(Compute only when required.)

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TABLE 6-5 (CONTINUED)
LAND APPLICATION METHODOLOGY
WORKSHEET

Item 10 - Monetary Cost Evaluation

i. Cost Schedule. (All costs: $ x 10^6)

Phase	Timing Yr to Yr	Item	Capital Cost	Start O&M	End O&M	Variable O&M	Salvage Value	Revenues[2] Start	Revenues[2] End
1	1 - 20	#6*	10.66	0.44	0.67	-	3.76	0	0
		#7	Cost for land included in item 8						
		#8	3.56	0.12	0.20	-	0.40	0	0
		#9	17.00	0.49	0.93	-	5.67	0.06	0.14
	TOTAL PHASE 1		31.22	1.05	1.80	0.038[1]	9.83	0.06	0.14
2		#6							
		#7							
		#8							
		#9							
	TOTAL PHASE 2								
3		#6							
		#7							
		#8							
		#9							
	TOTAL PHASE 3								

*Assumed Cost to allow completion of example.

1 Variable O+M (Phase 1) = $\frac{1.80 - 1.05}{20} = 0.038$

2 Variable Revenue (Phase 1) = $\frac{0.14 - 0.06}{20} = 0.004$

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TABLE 6-5 (CONTINUED)
LAND APPLICATION METHODOLOGY
WORKSHEET

Item 10 - Monetary Cost Evaluation (Continued).

Phase	Timing Yr to Yr	Item	Capital Cost	Start O&M	End O&M	Variable O&M	Salvage Value	Revenues Start	Revenues End
4		#6							
		#7							
		#8							
		#9							
	TOTAL PHASE 4								

Replacement Schedule ($ x 10^6)

Item	Year	Cost
8	15	1.00

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TABLE 6-16
PRESENT-WORTH METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgements presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach available (or even as the preferred approach). However, any approaches used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other EPA, State, and local guidelines and regulations.

Items 1-10 Present-Worth Calculation.

Planning Period 20 years Interest 7 %

	Item (Reference Page)	Amount		Present-Worth
1.	Phase 1 Capital (pg. 48)	31,220,000 x	1.0 (Yr 1)	31,220,000
2.	Phase 2 Capital (pg. ___)	____ x	____ ($sppwf^a$) (Yr ___)	____
3.	Phase 3 Capital (pg. ___)	____ x	____ ($sppwf^b$) (Yr ___)	____
4.	Phase n Capital (pg. ___)	____ x	____ ($sppwf^c$) (Yr ___)	____
5.	Replacement year (h) (pg. ___)	1,000,000 x	0.36 ($sppwf^h$) (Yr 15)	360,000
6.	Replacement year (i) (pg. ___)	____ x	____ ($sppwf^i$) (Yr ___)	____
7.	Replacement year (j) (pg. ___)	____ x	____ ($sppwf^j$) (Yr ___)	____
8.	Replacement year (k) (pg. ___)	____ x	____ ($sppwf^k$) (Yr ___)	____
9.	Replacement year (l) (pg. ___)	____ x	____ ($sppwf^l$) (Yr ___)	____
10.	Salvage Value (Negative Cost) (pg. 48)	-9,530,000 x	0.26 ($sppwf^z$) (Yr 20)	-2,560,000

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TABLE 6-16 (continued)
PRESENT-WORTH METHODOLOGY
WORKSHEET

Item 11 - 19 Present-Worth Calculation.

Planning Period 20 years Interest 7 %

	Item (Reference Page)	Amount		Present-Worth
11.	O&M Phase 1 Constant (pg. ___)	1,050,000	x 10.6 (uspwf[d]) x 1.0 (#Yrs 20 ; Yr 1)	11,100,000
12.	O&M Phase 1 Variable (pg. ___)	38,000	x 77.5 (gspwf[d]) x 1.0 (#Yrs 20 ; Yr 1)	2,950,000
13.	O&M Phase 2 Constant (pg. ___)	_____	x ____ (uspwf[e] x sppwf[a]) (#Yrs ___ ; Yr ___)	_____
14.	O&M Phase 2 Variable (pg. ___)	_____	x ____ (gspwf[e] x sppwf[a]) (#Yrs ___ ; Yr ___)	_____
15.	~~O&M~~ Revenue* Phase 1 A Constant (pg. ___)	-60,000	x (10.6)(1.0) (uspwf[f] x sppwf[b]) (#Yrs 20 ; Yr 1)	-640,000
16.	~~O&M~~ Revenue* Phase 1 A Variable (pg. ___)	-4,000	x (77.5)(1.0) (gspwf[f] x sppwf[b]) (#Yrs 20 ; Yr 1)	-310,000
17.	O&M Phase n Constant (pg. ___)	_____	x ____ (uspwf[g] x sppwf[c]) (#Yrs ___ ; Yr ___)	_____
18.	O&M Phase n Variable (pg. ___)	_____	x ____ (gspwf[g] x sppwf[c]) (#Yrs ___ ; Yr ___)	_____
19.			TOTAL PRESENT-WORTH	$ 42,120,000

*Negative cost

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Illustrative Example Supplemental Notes

In many situations, the user would wish to evaluate another potential land application site. This would be done by repeating the calculations for Items 5, 6, 7, 8, 9, and 10 and inserting them at this location. After evaluating all alternatives, the user would continue to Item 11.

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TABLE 6-5 (CONTINUED)

LAND APPLICATION METHODOLOGY
WORKSHEET

PRESENT-WORTH COST EVALUATION

Item 11 - Present-Worth Cost.

Site	Present-Worth Cost	Reference Sheet
1	$42,120,000	50,51

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Illustrative Example Supplemental Notes

The reuse of the treated wastewater from Source 1 is evaluated in the following worksheets. This example is not complete in that Present-Worth costs are not computed. However, the cost schedules specific to this evaluation are developed with appropriate commentary.

The potential reusers identified in this example currently use irrigation water from groundwater wells. For this example, additional treatment of the treated wastewater is assumed necessary for the reuser's use to demonstrate the development of the additional treatment cost. Also developed is a cost schedule for the reuser's alternative water cost for the replaceable portion of their water supply (i.e., the portion that could be replaced by treated wastewater).

These wastewater reuse cost evaluations develop two Present-Worth costs. The first is the estimated cost incurred for transportation and treatment of the wastewater for reuse. The second is the alternative cost of the reuser utilizing the projected water supply. Comparison of these two costs indicates which represents the least monetary cost, and thus indicates if an economic incentive might exist for reuse (i.e., reuse cost less than projected supply cost).

If reuse appears economically attractive, the user can develop total project costs for reuse by using the appropriate component methodologies. The Present-Worth cost of the total project would be carried to the FRAMEWORK METHODOLOGY WORKSHEET, page 8, to compare with other control alternatives.

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TABLE 6-12
WASTEWATER REUSE METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgments presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach available (or even as the preferred approach). However, any approach used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other EPA, State, and local guidelines and regulations.

Item 1 - General Reuse Criteria.

i.	Total municipal water demand approaching existing water supply?	YES	(NO)
ii.	Existing water supplies unavailable or insufficient for new uses (e.g., irrigation, industry)?	YES	(NO)
iii.	Existing water supply subject to environmental degradation (e.g., salt water intrusion, aquifer drawdown)?	YES	(NO)
iv.	Point source wastewater effluent available in sufficient quantity to satisfy potential new needs?	(YES)	NO
v.	Point source disposal technique involves unusually high costs?	(YES)	NO
vi.	Planning area includes any large uses of non-potable water?	(YES)	NO
vii.	Absence of restrictions (riparian rights) or related water law?	(YES)	NO
viii.	Expressed interest on the part of potential wastewater reusers?	(YES)	NO

Note: The user should determine from the answers to these general questions the relative demand for reuse. This is a judgment to be made by the planner or engineer.

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TABLE 6-12 (continued)
WASTEWATER REUSE METHODOLOGY
WORKSHEET

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Item - Potential Reuse Source Identification

Potential water reuse identification	Water source/ treatment	Water use	Present water cost	Projected water cost	Quantity: Current	Quantity: Design Yr	Quality: Desired	Quality: Minimum	Reliability	Distance
EXAMPLE:										
1. Georgia Power Plant, "Stechell" Mr. John Phillips Plant Engineer	Flint River/ screened, settled.	Cooling water	$0.12/1000 gal	$0.24	1.4 mgd (0.6 mgd firm minimum)	1.5 mgd (1985)	7.0< pH, T..	>6.0< pH 7.0-7.5	complete	3 miles, across Flint River
2. Blue Valley Pecan Farm, Mr. Tom Young, Owner	Private well, no treatment	Irrigation	$.04/1000 gal pumping cost	$0.22	400,000 gpd (May-Sept)		No toxic metals, low diss. solvents solids, normal pH	same	low	2 miles
Albany County Club	Private well, no treatment	Irrigation	$.12/1000 gal pumping cost	$0.36	200,000 gpd (May-Sept)	300,000 gpd (1985)	none		low	8 miles

Note: the above example data will be utilized in the illustrative example.

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TABLE 6-12 (continued)
WASTEWATER REUSE METHODOLOGY
WORKSHEET

POTENTIAL REUSER EVALUATION
Reuser: #2, Blue Valley Pecan Farm, Albany Country Club

Item 3 - Point Source Treatment to Meet Reuse Criteria.

	Reference Cost Curve	Reuser/Point Source Critical Parameters							
		Q	BOD	TSS	N	P	T	TDS	Cl2
Reuser Water Quality Requirements *	N/A	mg/l 0.7	mg/l 19	mg/l 26	-	-	-	mg/l 658	mg/L -
Existing Wastewater Effluent Quality	H-3	9.0	100	50	-	-	-	-	-
Existing Wastewater Effluent Quality Control Criteria	H-12	9.0	5	5	-	-	-	-	-
Upgrade Technique[1]	H-59	0.7	None	None				None	H-59

[1]Identify the cost curve for upgrading each identified parameter to the reuser criterion; identify the required system under "Reference Cost Curve" from individual curves.

Item 4 - Treatment Requirement Cost Schedule to Meet Reuser Criteria.

(Use TREATMENT FACILITY METHODOLOGY to define costs for treatment above that required for discharge)

Phase	Timing Yr.	to Yr.	Capital	O&M Start	O&M End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Existing Facility	Existing facility must be upgraded to H-12 level for discharge							
1	1	20	37,000	6,000	9,000	15	12,000	None
2								
3								
n								

* Reuser water quality requirements from Table 6-14. The requirements for zero chlorine residual is for illustrative purposes only, and does not represent a real situation.

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Remarks: Reference pages 58-61 describe costs for Item 4. Page 57

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TABLE 6-4
TREATMENT FACILITY METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgments presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach available (or even as the preferred approach). However, any approaches used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other FPA, State, and local guidelines and regulations.

Item 1 - Program Implementation Schedule.

i. Planning Period: 20 years

ii. Construction phases: 1

Phase	Timing Year	to	Year	Flow Projection (mgd) Start	End	Design Flow (mgd)
1*	Present	to	N/A			
≈1	1	to	20	0.7	1.5	1.5
3		to		assumes Blue		
4		to		Valley growth		
n		to		to 800,000 ~~gpd~~ demand		

*Existing facility not utilized at full capacity.

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TABLE 6-4 (continued)
TREATMENT FACILITY METHODOLOGY
WORKSHEET

iii. Treatment Objectives.

Note: Dissolved oxygen deficits use ultimate oxygen demand inputs (Table 6-3). These must be reconverted back to CBOD and NBOD (NH_3) concentrations to determine discharge limitations (See Appendix H discussion of Treatment Systems Performance Matrix).

	Effluent Quality								
Phase	Reference Cost Curve**	BOD mg/l	COD mg/l	TSS mg/l	T-P mg/l	NH_3-N mg/l	NO_3-N mg/l	T-N mg/l	T-C #/100ml
Existing Facility	Not Applicable - looking at treatment above discharge limit								
1	H-59								≈0
2									
3									
n									

**Treatment System curve number (Appendix H, Figures H-2 to H-15) or reference number for synthesized system cost curve developed from unit process curves (Appendix H).

iv. Existing Facility Characteristics.

Design Capacity: None mgd

Service Life: _____ years

Years in Service: _____ years

Remaining Service: _____ years

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Remarks: New facility for treatment + merge of treated effluent Page 59

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TABLE 6-4 (CONTINUED)
TREATMENT FACILITY METHODOLOGY
WORKSHEET

Item 3 - Expansion Program or (New Facility Construction.)

Phase Number 1

i. Existing Capacity = None mgd (previous phase or existing facility; zero if new facility)

ii. Expanded or New Facility Capacity = 1.5 mgd (design capacity of next phase)

iii. Level of Treatment: Reference Cost Curve H-59
Service Life 15 yr

iv. Construction cost of expanded or new facility - enter cost curve at expanded or new facility at capacity (ii) $20,000

v. Construction cost of existing facility - enter cost curve at existing facility at capacity (i) —

vi. Sub-Total 1: Expanded or New Facility Construction Cost (iv-v) = $20,000

vii. plus Sub-Total 1 x Piping 15% = 3,000
Sub-Total 1 x Electrical 12% = 2,400
Sub-Total 1 x Instrumentation 8% = 1,600
Sub-Total 1 x Site Preparation 5% = 1,000

viii. Sub-Total 2: Construction Cost (vi + vii) $28,000

ix. plus Sub-Total 2 x Expansion/Upgrading Factor N/A = —
Sub-Total 2 x Engineering and Construction 15% = 4,200
Sub-Total 2 x Contingencies 15% = 4,200

x. Sub-Total 3: Capital Cost (viii + ix) $36,400

xi. CAPITAL COST OF EXPANSION OR OF NEW FACILITY = Sub-Total 3 x ENR (Current) / 2475* 2499/2475 = $37,000

* ENR = 2475, September, 1976.

Note: Items 2 and 4 not included because these calculations are not required.

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TABLE 6-4 (CONTINUED)
TREATMENT FACILITY METHODOLOGY
WORKSHEET

Item 5 - O&M Constant and Variable Cost.

Phase 1

Level of Treatment: Reference Cost Curve H-19

Timing Start (yr.)	Timing End (yr.)	Design Flow Start (mgd)	Design Flow End (mgd)	O&M Cost Start	O&M Cost End
1	20	0.7	1.5	$6,000	$9,000

Item 6 - Phase ____ Replacement Costs (Upgraded and/or Expanded Portion)
(Compute if planning period is greater than phase service life)
Replacement Cost Schedule.

~~Expansion~~ New Year	~~Expansion~~ New Cost	Upgrading Year	Upgrading Cost	Total Year	Total Cost
15	12,000			15	12,000

Replacement Cost for Phase 1 =

$$\frac{\text{Years from Time of Replacement to end of Planning Period}}{\text{Service Life}} \times \text{Capital}$$

$$RC = \frac{20-15}{15} \times 37{,}000 = 12{,}000$$

Item 7 - Phase 1 Salvage Value at End of Planning Period.
(Compute if phase service life is greater than years to planning period end)

$$\text{Salvage Value} = \frac{\text{(Service Life - Years to Planning End)}}{\text{Service Life}} \times \text{Capital}$$

~~Expansion~~ New S.V. = None $ None

Upgrading S.V. = $ ____

Total Phase S.V. $ None

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TABLE 6-12 (continued)
WASTEWATER REUSE METHODOLOGY
WORKSHEET

Item 5 - Reuse Transportation Cost Schedule.

Phase	Timing Yr. to Yr.		Capital	O&M Start	O&M End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Existing Facility			Not Applicable					
1 *	1	20	2,200,000	20,000	30,000	15	80,000	1,200,000
2								
3	*Costs are assumed for illustrative purposes.							
n								

Item 6 - Wastewater Reuse Project Costs.

i. Project Cost Schedule.

Phase	Timing Yr to Yr	Item	Capital Cost	Start O&M	End O&M	Variable O&M	Salvage Value
1		#4	37,000	6,000	9,000	-	0
		#5	2,200,000	20,000	30,000	-	1,200,000
	TOTAL PHASE 1		2,240,000	26,000	39,000	700	1,200,000
2		#4	Variable O+M = $\frac{39,000 - 26,000}{20}$				
		#5					
	TOTAL PHASE 2						
3		#4					
		#5					
	TOTAL PHASE 3						

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Remarks: Atlanta WASTEWATER REUSE METHODOLOGY Page 62

TABLE 6-12 (continued)
WASTEWATER REUSE METHODOLOGY
WORKSHEET

Item 6 - Wastewater Reuse Project Costs (continued).

Phase	Timing Yr to Yr	Item	Capital Cost	Start O&M	End O&M	Variable O&M	Salvage Value
n		#4					
		#5					

TOTAL PHASE n

Replacement Schedule

Year	Cost
15	12,800
15	80,000

ii. Present-Worth Cost (using PRESENT WORTH METHODOLOGY).

Interest 7 %

Present-Worth Cost $_____

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TABLE 6-12 (continued)
WASTEWATER REUSE METHODOLOGY
WORKSHEET

Item 7 - Reuser Replaceable Water Costs.
(Cost that would be incurred for replaceable water supply without wastewater recycle)

i. Cost Schedule.

Phase	Timing Yr to Yr	Recycle Water Use[1], gpd Start	End	Unit Water Cost[2] $/1000 gal Start	End	Annual Water Cost[3], $/year Start	End
1	1 20 Bear Valley	400,000	800,000	0.09	0.22	6,800	37,000
2 1	1 20 Albany CC	300,000	700,000	0.14	0.38	8,900	57,000
3							
n							

[1]Recycle Water Use represents the portion of total reuser water requirement that could be satisfied by treated wastewater.
[2]Unit Water Cost represents projected cost for existing supply if adequate, or the unit cost for development and treatment of a new supply.
[3]Annual Water Cost = (gpd) ($/gal) (365 days/yr) (required May - Nov. from Item 2)

ii. Reuser Replaceable Water Present-Worth Cost.
(using PRESENT-WORTH METHODOLOGY): $_____

Item 8 - Wastewater Reuser Relative Costs.

i. Replaceable Water Cost: $_____
(Alternative Present-Worth cost for reuser water needs that can be satisfied during the planning period by treated wastewater; from Item 7 ii)

ii. Reused Wastewater Cost: $_____
(Present-Worth cost to utilize treated wastewater; from Item 6 ii)

iii. Other Factors: (describe factors other than cost that will affect further evaluation)

Further evaluation depends upon the location of additional reusers in the vicinity of these reusers to share the cost of a force main system. Also, if a substantial reuser were identified a reliable, the required treatment facility cost could be reduced.

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TABLE 6-12 (continued)
WASTEWATER REUSE METHODOLOGY
WORKSHEET

Item 9 - Potential Reuser/Point-Source Combinations

Point Source		Reuser		Identified Present-Worth Costs			
ID	Q,mgd	ID	Q,mgd	Wastewater Reuse	Replaceable Water	Total	Non-Monetary Cost Incentive

None identified

Note: The user would normally continue evaluation of reuse candidates at this point, and would then transfer pertinent information on the favorable candidates to Item 9.

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Illustrative Example Supplemental Notes

The following worksheets outline the evaluation of Impact Area Modifications as a control alternative for Source 1. This portion of the example is not worked to completion because the required cost computations have been previously demonstrated in the treatment facility and land application control alternatives evaluations. However, the determinations specific to this methodology have been utilized.

The general receiving water condition in this example has been defined using the water quality impact analysis techniques in Chapter 5 of this manual, which consider all contributing sources and their relative impact. This information identifies the potential usefulness of the modifications presented in this example.

If the discharge relocation example had been carried further, the Chapter 5 impact analysis would be utilized to determine the level of treatment at the proposed discharge site. If a reduced treatment level were indicated, then a cost reduction for treatment might be realized, depending on the magnitude of the transportation cost that would also be incurred.

Artificial reaeration is not a viable control alternative for this example because the critical water quality parameters are nitrogen and phosphorus, which would not be substantially affected by reaeration. The information and steps that would be considered for a potential situation are indicated on the worksheets.

Flow augmentation also is not a viable control alternative for this example because the critical water quality condition is defined by the long-term concentration of nitrogen and phosphorus, but this modification is appropriate primarily to relieve a short-term stiuation. The worksheets have been marked to indicate the appropriate entries to be made when this evaluation is appropriate.

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Remarks:		Page	66

TABLE 6-14
IMPACT AREA MODIFICATION METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgments presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach available (or even as the preferred approach). However, any approach used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other EPA, State, and local guidelines and regulations.

Item 1 - Receiving Water Quality.

Source # 1

Water Quality Conditions:

The user is referred to Table 6-2 which describes the desired water quality in the South River for this hypothetical example. The information in this table is used to identify which impact area modifications might alleviate the undesireable water quality conditions.

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TABLE 6-14
IMPACT AREA MODIFICATION METHODOLOGY
WORKSHEET

Discharge Relocation Evaluation.

Item 2 - General Criteria for Discharge Relocation.*

1.	Is this source a principal cause of the critical stream condition?	(YES)	NO
2.	Are there several significant sources near this source?	(YES)	NO
3.	Would relocation be relatively inexpensive? (one other could be)	(YES)	NO
4.	Is there a major (or larger) stream nearby that could receive the source?	YES	(NO)

Item 3 - Alternate Discharge Site Identification.

(Factors: Less stringent water quality criteria; lower net source loading; increased dilution due to tributary flow)

	Site	Location	Distance
a)	Mile 30	Downstream from confluence of Rivers 1 and 5	Approx. 10 miles
b)			
c)			

Reference Figure 2-4, Map of Hypothetical Planning Area, South River, USA.

* These evaluations are qualitative in nature and will be useful in defining priorities for further cost evaluations.

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TABLE 6-14 (CONTINUED)
IMPACT AREA MODIFICATION METHODOLOGY
WORKSHEET

Site _____ Evaluation

Item 4 - Modified Source Level of Treatment (from Impact Analysis, Chapter 5).

Level	Reference Cost Curve	Parameter Control Levels							
		BOD mg/l	COD mg/l	TSS mg/l	T-P mg/l	NH_3-N mg/l	NO_3-N mg/l	T-N mg/l	T-C #/100ml
Existing Discharge Site		This information would be defined by the results of the Chapter 5 Impact Analysis. The required level of treatment (indicated by the Reference Cost Curve) should be lower for any alternative Discharge Site that is investigated further.							
Alternate Discharge Site A									
Alternate Discharge Site B									

Item 5 - Discharge Relocation Transportation Cost Schedule.
(use the TRANSPORTATION COST METHODOLOGY)

Phase	Timing Yr. to Yr.		Capital	O&M Start	O&M End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Existing Facility								
1			This cost schedule is developed					
2			as previously demonstrated.					
3								
n								

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TABLE 6-14 (CONTINUED)
IMPACT AREA MODIFICATION METHODOLOGY
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Item 6 - Modified Treatment Level Cost Schedule.
(use TREATMENT FACILITY METHODOLOGY)

Phase	Timing Yr.	to Yr.	Capital	O&M Start	O&M End -	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Existing Facility								
1			This cost schedule is developed					
2			as previously demonstrated.					
3								
n								

Item 7 - Project Cost.

i. Project Cost Schedule.

Phase	Timing Yr.	to Yr.	Capital	O&M Start	O&M End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Existing Facility								
1			This schedule combines the costs from					
2			Items 4, 5, 6 and any other					
3			identified cost.					
n								

ii. Project Present-Worth Cost: $_____
(use PRESENT-WORTH METHODOLOGY)

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TABLE 6-14

IMPACT AREA MODIFICATION METHODOLOGY
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ARTIFICIAL REAERATION EVALUATION

Item 8 - Receiving-Body Dissolved Oxygen Requirements.

Condition		Dissolved Oxygen, mg/l	@	Location
Water Quality Limit	(1)	5.0 mg/L / 4.0 mg/L		M.P. 0→20/20→35
Critical Level	(2)	(Deficit) None / 3.10 mg/L		M.P. 19.5/23

References: (1) - Table 6-1; (2) - Table 6-2.

Item 9 - Modified Stream Quality at Revised Source Loads.
(developed from Impact Analysis, Chapter 5)

	Wastewater Load Parameter	Discharge Level	Resulting Minimum Stream DO	@	Location
A.	BOD		Not affected	@	
	TSS	Not affected			
	T-N/P	Not affected by reaeration			
B.	BOD			@	
	TSS				

Note: the user would determine the resulting stream D.O. at a modified load condition in the case where total nitrogen and phosphorus were not critical.

Item 10 - Artificial Reaeration Requirement.

i. Oxygen-Transfer Requirements.

Stream flow rate at critical conditions: (from stream data) cfs

Critical DO level: 3.10 mg/l (deficit)

Minimum acceptable DO level: 4.0 mg/l (from stream data)

Oxygen transfer requirement: (calculate) lb/hr for _____ hr/yr

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TABLE 6-14 (CONTINUED)
IMPACT AREA MODIFICATION METHODOLOGY
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Item 10 - Artificial Reaeration Requirement (continued).

ii. Reaeration Project Phasing.

Phase	Timing Yr to Yr		Reaeration Oxygen Demand, lb/hr Start	End	Capital	O&M Start	O&M End	Replacement Cost	Salvage Value
1			This cost schedule would be developed						
2			using site-specific information and						
3			the TREATMENT FACILITY worksheets.						
n									

Item 11 - Treatment Cost Schedule at Modified Treatment Level.

Phase	Timing Yr. to Yr.		Capital	O&M Start	O&M End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Existing Facility								
1			This cost schedule is developed					
2			as previously demonstrated.					
3								
n								

Item 12 - Artificial Reaeration Project Cost.

i. Project Cost Schedule.

Phase	Timing Yr. to Yr.		Capital	O&M Start	O&M End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Existing Facility								
1			This cost schedule can be developed					
2			using the TREATMENT FACILITY					
3			worksheet.					
n								

ii. Project Present-Worth Cost: $_____

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TABLE 6-14 (CONTINUED)
IMPACT AREA MODIFICATION METHODOLOGY
WORKSHEET

FLOW AUGMENTATION EVALUATION

Item 13 - General Applicability of Flow Augmentation as a feasible control alternative.

Do critical water quality conditions occur at low flow?
(Yes or no) Yes Critical Parameters, if yes: D.O. (no for N-P)

Comments: (Special conditions, model assumptions, reference sheets)

See Tables 6-1 and 6-2.

Item 14 - Flow-Augmentation Capability.

i. Existing Reservoir low-flow augmentation capacity: from water supply data cfs
Duration: _____ days

ii. Proposed Reservoir low-flow augmentation capacity: this would be a site specific determination cfs
Duration: _____ days

Item 15 - Modified Source Load Control with Flow Augmentation.

i. Available Flow for Augmentation for the required duration (Item 14) cfs

ii. Revised stream low flow Item 14 and Item 10 source

iii. Revised Level of Treatment from Impact Analysis (Chapter 5) performed with the original pollutant loads and the revised stream flow in (ii) above.

	Critical Parameter	Revised Control Level
a)		
b)		

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TABLE 6-14 (CONTINUED)
IMPACT AREA MODIFICATION METHODOLOGY
WORKSHEET

Item 16 - Flow Augmentation Cost

i. Modified Level of Treatment Cost Schedule.

Phase	Timing Yr. to Yr.		Capital	O&M Start	O&M End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Existing Facility								
1			This cost schedule is developed					
2			using the TREATMENT FACILITY					
3			worksheets.					
n								

ii. Flow Augmentation Cost Schedule.

Phase	Timing Yr. to Yr.		Capital	O&M Start	O&M End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Existing Facility			This cost schedule can be developed using					
1			the TREATMENT FACILITY worksheets in					
2			certain situations. However, in many cases,					
3			this information would be available from					
n			existing water supply surveys.					

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TABLE 6-14 (CONTINUED)
IMPACT AREA MODIFICATION METHODOLOGY
WORKSHEET

Item 16 - Flow Augmentation Cost (continued).

iii. Project Cost Schedule.

Phase	Year to Year	Item	Capital Cost	Start O&M	End O&M	Variable O&M	Salvage Value
1		16i	This cost schedule is developed				
		16ii	as demonstrated in other similar				
			cost schedule tables.				
	Total Phase 1						
2		16i					
		16ii					
	Total Phase 2						
3		16i					
		16ii					
	Total Phase 3						
n		16i					
		16ii					
	Total Phase n						

Replacement Schedule

Year	Cost

iv. Project Present-Worth cost.

Interest _____%

Present-Worth Cost $_____

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Illustrative Example Supplemental Notes

The evaluation process of Strategy 9 would normally continue at this point with an evaluation of the control alternatives for the next source, as indicated by the flow diagram (Figure 6-6). The evaluation of Source 2 control alternatives is identical to that shown for Source 1; therefore, these calculations have not been included in this example.

Following the evaluation of all sources for each strategy, the evaluation of regionalized control facilities is investigated. The following worksheets demonstrate one approach for regionalization.

Typical information concerning potential site identification and evaluation has been included in the appropriate worksheet items. However, other factors may be more significant for the planner's area of interest.

This example demonstrates regionalization of residuals disposal as well as treatment facilities. Again, only the information concerning site identification has been indicated since all cost determinations are similar to those presented in previous methodologies.

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TABLE 6-15
REGIONALIZATION METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgments presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach available (or even as the preferred approach). However, any approach used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other EPA, State, and local guidelines and regulations.

Wastewater Treatment Regional Site Evaluation

Item 1 - Source Identification.
(Attach topographic map with sources located)

	Source/Location	Flow	Level of Control/ Critical Parameters
a)	1 / SD#1	9 → 17	Curve H-12/S-1*
b)	2 / SD#2	11 → 30	Curve H-12
c)			
d)			
e)			
f)			
g)			
h)			
i)			
j)			
k)			
l)			
m)			
n)			

* See page 11.

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TABLE 6-15 (continued)
REGIONALIZATION METHODOLOGY
WORKSHEET

Item 2 - Regional Site Identification.
(Attach topographic map with sources located)

	Site/Location	Available Area (acres)	Estimated Max. Flow -(mgd)	Existing Condition
a)	SD #1 STP	30	60	9 mgd primary STP
b)	SD #2 STP	25	70	12 mgd secondary STP
c)	S. River, 2 miles	110	400	Farmland and
d)	downstream of SD #1 STP			light forest,
e)				undeveloped.
f)				
g)				
h)				
i)				
j)				
k)				
l)				
m)				
n)				

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TABLE 6-15 (continued)
REGIONALIZATION METHODOLOGY
WORKSHEET

Item 3 - Potential Regional Site/Source Combinations.

Combination I.D. No.	Source 1		Source 2		Regional Site		
	I.D.	Q (mgd)	I.D.	Q (mgd)	I.D.	Max Site Q (mgd)	Max Design Q (mgd)
1	a) SD#1	17	b) SD#2	30	a) SD#1 STP	60	47
2	a) SD#1	17	b) SD#2	30	b) SD#2 STP	70	47
3	a) SD#1	17	b) SD#2	30	c) St. Louis Downstream	400	47

Note: This list presents a running account of the alternatives under consideration for wastewater reuse. More than two sources can be combined if desired.

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TABLE 6-15 (continued)
REGIONALIZATION METHODOLOGY
WORKSHEET

REGIONAL SITE EVALUATION

(S.D #1 + S.D. #2 @ S. River, 2 miles downstream of S.D. #1 STP)

Regional Combination No. 3

Item 4 - Level of Treatment at Regionalization Site.

	Parameter	Raw Wastewater	Discharge Level	Level of Treatment
a)	BOD			
b)	T-P		2 mg/L	H-12
c)	T-N		8 mg/L	H-12

Level of Treatment: H-12

Note: in the general case, the Chapter 5 impact analysis would be performed to define the level of treatment.

Item 5 - Regional Site Wastewater Treatment Cost Schedule.
(Use the TREATMENT FACILITY METHODOLOGY)

Phase	Timing Yr.	to Yr.	Capital	O&M Start	O&M End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Existing Facility			This cost is computed exactly as before with a new					
1			facility because this is a new site. In this example,					
2			a phase-out cost might exist if the facilities at					
3			S.D. #1 and S.D. #2 are not utilized.					
n								

Item 6 - Wastewater Transportation Cost Schedule.
(Use the TRANSPORTATION COST METHODOLOGY)

Phase	Timing Yr.	to Yr.	Capital	O&M Start	O&M End	Replacement Cost Year	Replacement Cost Cost	Salvage Value
Existing Facility			This cost is computed exactly as before for two flows					
1			in the pipeline: one for the flow between the					
2			two existing discharges, and for both flows combined.					
3								
n								

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TABLE 6-15 (continued)
REGIONALIZATION METHODOLOGY
WORKSHEET

Item 7 - Regionalization Cost Evaluation.

i. Cost Schedule (Regional Combination No. _____)

Phase	Timing Yr to Yr	Item	Capital Cost	Start O&M	End O&M	Variable O&M	Salvage Value
1		# 5	This schedule would be filled out as other similar schedules.				
		# 6					
	TOTAL PHASE 1						
2		# 5					
		# 6					
	TOTAL PHASE 2						
3		# 5					
		# 6					
	TOTAL PHASE 3						
4		# 5					
		# 6					
	TOTAL PHASE 4						

Replacement Schedule

Item	Year	Cost

ii. Present-Worth Project Cost: $_____

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TABLE 6-15 (continued)
REGIONALIZATION METHODOLOGY
WORKSHEET

Item 8 - Present-Worth Cost.

Regional Site I.D.	Source I.D. No. 1	Source I.D. No. 2	Separate Treatment Costs Source 1	Separate Treatment Costs Source 2	Regional Treatment Cost

The costs determined for each alternative are recorded here. The comparison of the individual treatment cost to the regionalized cost indicates if a monetary cost incentive exists. The results on this table should indicate the types of combinations that are most effective which will assist in the identification of additional combinations.

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TABLE 6-15 (continued)
REGIONALIZATION METHODOLOGY
WORKSHEET

Residuals Disposal Regional Site Evaluation

Item 9 - Residuals Generator Source Identification.

	Source/Location	Flow (mgd)	Residual Disposal Method	Residual Characteristics Quality	Type
a)	S.D. #1	17	landfill	dewatered (20%)	biological
b)	S.D. #2	30	landfill	dewatered (30%) (same)	chem. (lime)
c)					
d)					
e)					
f)					
g)					
h)					
i)					
j)					
k)					
l)					
m)					
n)					

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TABLE 6-15 (continued)
REGIONALIZATION METHODOLOGY
WORKSHEET

Item 10 - Potential Residual Disposal Sites.

	Site/Location	Available Area (acres)	Estimated Capacity	Existing Condition
a)	off Hwy 3, East of S.D. # 1	200	*	Site cleared (proposed site for S.D. # 1 landfill)
~~b)~~				
b)	S.D. # 2	20	*	Existing site for S.D. # 2
d)				
e)				
f)				
g)				
h)				
i)				
j)				
k)				
l)				
m)				
n)				

* This should be developed in terms of useful life for a design flow rate.
Eg. 50 years as landfill @ 30 mgd
(curve H-12 equivalent sludge)
or S-1

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TABLE 6-15 (CONTINUED)
REGIONALIZATION METHODOLOGY
WORKSHEET

Item 11 - Potential Regional Site/Generator Combinations.

	Regional Site		Generator			
	Site I.D.	Capacity	I.D.	Location	Quantity	
a.	off Hwy 3	adequate for 20 years	(a)	S.D. #1	17 mgd	S-1
			(b)	S.D. #2	30 mgd	H-12
b.						

Item 12 - Regional Site/Generator Combined Present Worth Costs.
(Using the RESIDUALS DISPOSAL METHODOLOGY)

	Combination Generator I.D.	Present Worth Cost at Combination	Present Worth Cost Separate
a.	off Hwy 3	*	**
	S.D. #1		**
	S.D. #2		
		TOTAL	
b.			
		TOTAL	

* This number would be computed using the information in Items 11 and the RESIDUALS DISPOSAL METHODOLOGY.

** This information would be available from previous computations.

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Illustrative Example Supplemental Notes

The monetary cost evaluation for achievement of Strategy 9 load reductions for Sources 1 and 2 is complete at this point. All costs for this evaluation have been entered in Table 6-3, Item 2, as they were generated.

The illustrative example continues at this point with an evaluation of wet weather, Sources 3 and 4.

The first of the control alternatives to be considered for wet weather sources is the LAND MANAGEMENT METHODOLOGY. For Source 3, the feasibility of controlling the TSS and TC loadings through land management is considered.

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TABLE 6-6
LAND MANAGEMENT METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgements presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach available (or even as the preferred approach). However, any approaches used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other EPA, State, and local guidelines and regulations.

Item 1 Land uses and land use activities of concern.

Land Uses and Land Use Activities[1]	Wasteload BOD5	N	P	TSS	TC[2]	Applicable Land Management Alternatives
Residential (low density)	NOTE: Wasteloads from these land uses can be generated using techniques presented in Chapters 2 and 3, or by equivalent methods					Sediment and erosion control program
Residential (Medium density)						Street sweeping
Residential (High density)						Street sweeping
Light Industry						Site runoff controls
Commercial						~~Street~~ sweeping

Item 2

	Percent Reduction BOD5	N	P	TSS	TC
i) Load reduction requirements:				65%	95%

ii) Land management alternative performance capability.

Land Uses and Land Use Activities	Applicable Land Management Alternative	Performance Range-Percent Reduction BOD5	N	P	TSS	TC
Residential (low density)	Sediment and erosion control program	(Would be determined by applying unit estimates (e.g. 5 lb BOD5/acre/yr) of pollutant removals to the areas under consideration and figuring percent removals based on estimated overall loadings)				
Residential (medium density)	Street Sweeping					
Residential (High density)	Street Sweeping					
Light Industry	Site Runoff Controls					
Commercial	Street Sweeping					

[1] See Table 6-7.
[2] Most probable number/100 ml

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TABLE 6-6 (continued)
LAND MANAGEMENT METHODOLOGY
WORKSHEET

Item 3 Identification of alternatives which will achieve required reduction.

Land Uses and Land Use Activities	Land Management Alternatives	Parameter	[Waste-load] X	[Performance Capa.] =	[Waste-load Red.]
Residential (high and medium density)	Street Sweeping	TSS			
Commercial	Street Sweeping	TSS			

Note: The implementation of a street sweeping program in the high- and medium-density residential and commercial areas was chosen for evaluation for illustrative purposes. This choice was based on the relative acreage of the land uses in Subarea 1, on the relative magnitude of contribution of the pollutants of concern, and on the potential effectiveness of a street sweeping program in achieving the required load reductions of total suspended solids (TSS). It is assumed that none of the land management alternatives applicable to Subarea 1 would achieve near the required reductions of the total coliform (TC); therefore, other control alternatives would have to be applied for this pollutant.

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TABLE 6-6 (continued)
LAND MANAGEMENT METHODOLOGY
WORKSHEET

Item 4 Capital and O&M Cost (From Appendix G).

Land Management Alternative	Affected Land Use/Activity (Acres)	Capital Cost	O&M Cost
Street Sweeping	~ 5,000 acres	(Would be determined by applying unit estimates [eg. $/curb-mile/year] to areas of concern)	

Item 5 Present worth cost of land management alternatives.

Land Management Alternatives	Present Worth Cost	Information Reliability[1] Performance	Cost
Street Sweeping	(Using PRESENT-WORTH METHODOLOGY)	(Based on judgment of the user)	

[1] From Appendix G

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Illustrative Example Supplemental Notes

The degree of pollutant reduction achievable through land management control alternatives may or may not be what is required by the load reduction strategy. Therefore, collection system controls, the next wet-weather control alternative in the framework (Figure 6-6), may be evaluated as an additional control alternative or as an alternate approach. In this example, collection system controls will be evaluated as a separate control alternative.

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TABLE 6-8
COLLECTION SYSTEM CONTROL METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgments presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach available (or even as the preferred approach). However, any approaches used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other EPA, State and local guidelines and regulations.

Item 1 Sewer System Characteristics.

Outfall No.	Subarea Location[1]	Sewer Segment Type[2]	Type of Overflow Control Device[3]
1			
2			
3	Subarea 1 *	Combined	Regulator (rev.)
4	Subarea 2*	Storm	None
5			

* See map, page 2.

[1]Locations should be referenced to a map using outfall and subarea numbers.

[2]Combined sewer, storm sewer or unsewered.

[3]Swirl separator or conventional regulator.

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TABLE 6-8 (continued)
COLLECTION SYSTEM CONTROL METHODOLOGY
WORKSHEET

Item 2 Pollutants (BOD_5, TSS, TC, P, N) to be controlled (from Load Reduction Strategy Matrix, Table 6-19).

Segment No.	Pollutant Parameter	Required % Reduction
3	TSS TC	65% 95%
4	UOD TC	39% 99.8%

Item 3 In-line storage volume.

Segment No.	Hydraulic Capacity	Dry Weather Flow	Internal Storage Capacity
3 (first segment considered)	See note	See note	0.8 million gallons (assumed for example)

NOTE: Here the user would prepare a schematic of the sewer segment which indicates the routing, interconnections, interceptor capacities, and other features similar to Figure 3-19 on page 3-76 of this manual. The hydraulic capacity of the interceptors can be determined from standard pipe flow equations. Dry weather flow to the combined sewer can be estimated using contributing population times a gallons per capita factor. Internal storage capacity can be determined using a simulator, as described in Section 3.4.4, by considering existing excess hydraulic capacity over the dry weather flow, as in Table 3-8, and using slopes to determine available volumes, or by other methods. For this example, it is assumed that 10 weirs placed at various locations in sewer segment #1 will result in an internal storage of 0.8 million gallons.

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TABLE 6-8 (continued)
COLLECTION SYSTEM CONTROL METHODOLOGY
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Item 4 Cost of utilizing available in-line storage from cost information information in Appendix G, or an equivalent method.

Segment No.	Type of Control[1]	Construction Costs	O&M Cost	Total Present Worth Costs[2]
3	10 weirs	(Determine costs using EPA or other appropriate guidance)		

Item 5 Sewer segments with deposition problems.

Segment No.	Extent of Problem	Source of Problem[3]
3	(1) 1500' between manholes 7 and 11	Slope allows solids to settle.
	(2) 1000' between manholes 22 and 25	Slope allows solids to settle

[1] Weir, gate, etc.

[2] Using PRESENT-WORTH METHODOLOGY

[3] Obstructions, slack velocity, etc.

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TABLE 6-8 (continued)
COLLECTION SYSTEM CONTROL METHODOLOGY
WORKSHEET

Item 6 Impact of sewer flushing on pollutant concentrations in overflows.

Outfall No.	Segment No.	Pollutant Parameter	Concentration Before	Concentration After
3	3	TSS TC	372 mg/L no change	340 mg/l *

*NOTE: Concentration after flushing assumed for example purposes. The impact of sewer flushing will have to be estimated depending on the performance data found in Appendix 6. The impact will be highly site-specific and will depend on the design storm, the magnitude of runoff, the extent of flushing, and other factors.

Item 7 Cost of sewer flushing using cost information, in Appendix G, or an equivalent method.

Segment No.	O&M	Total Present-Worth Costs
3	(See Appendix G or other appropriate guidance for estimating sewer flushing costs)	

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TABLE 6-8 (continued)
COLLECTION SYSTEM CONTROL METHODOLOGY
WORKSHEET

Item 8 Cost of measuring conveyance capability using cost curves in Appendix G or an equivalent method.

i. Polymer injection costs.

Segment No.	Construction Costs	O&M Costs	Total Present-Worth Costs[1]
3	(Determine costs using EPA or other appropriate guidance)		

ii. Increased Pumping capacity at the wastewater treatment plant where influent interceptor is surcharged.

Existing Capacity	Increased Capacity	Construction Cost	O&M Costs	Total Present-Worth Costs[1]
		None		

[1]Using PRESENT-WORTH METHODOLOGY

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TABLE 6-8 (continued)
COLLECTION SYSTEM CONTROL METHODOLOGY
WORKSHEET

Item 9 Cost of other collection system controls as appropriate, using Appendix G or an equivalent method.

Segment No.	Type of Control	Construction Costs	O&M Costs	Total Present-Worth Costs[1]
		None		

[1]Using PRESENT-WORTH METHODOLOGY

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TABLE 6-8 (continued)
COLLECTION SYSTEM CONTROL METHODOLOGY
WORKSHEET

Item 10 Collective effect on runoff volumes and loads of all collection system controls found to be feasible.

Segment No.	Control Alternative	% Runoff Controlled	Pollutant Parameter	Load Reduction Achieved
3	In-line storage	0.8 mg		
3	Sewer flushing of two sections		TSS	70 mg/L *
3	Polymer injection	*		*

(This table would be filled out similarly for each of the critical sewer segments and the collective effect of the controls would be added up.)

*NOTE: It will be assumed for this example that enough TSS are to be removed by sewer flushing to reduce the required load reduction from the remaining overflow from 65% to 60%. Polymer injection results in improved conveyance capability which is very difficult to represent quantitatively as a runoff control or load reduction.

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TABLE 6-8 (continued)
COLLECTION SYSTEM CONTROL METHODOLOGY
WORKSHEET

Item 11 Summary of feasible collection system control alternatives.

Collection System Control	Present-Worth Costs
In-line storage	(Costs from previous
Sewer flushing	calculations)
Polymer injection	

Total _____

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Illustrative Example Supplemental Notes

The investigation of storage/treatment options in this example takes into account the internal storage achieved in the collection system. A storage/treatment option is selected for evaluation which involves storage and treatment of the storm overflow at the overflow site. Other options are covered in the discussion.

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TABLE 6-9
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

The procedures, calculations, assumptions, and judgments presented in the flowcharts and worksheets are for guidance only, and should not be interpreted as the only approach available (or even as the preferred approach). However, any approaches used should be consistent with EPA Cost Effectiveness Analysis Guidelines and all other EPA, State, and local guidelines and regulations.

Item 1 Sewer System Characteristics.

Outfall No.	Subarea Location[1]	Sewer Segment Type[2]	Type of Control Device[3]
3	Subarea #1 (see map, page 2)	Combined	Regulator (weir)
4	Subarea #2 (see map, page 2)	Storm	None

Note: This information is the same as that in Item 1 of COLLECTION SYSTEM CONTROL METHODOLOGY Illustrative Example worksheet, page 91.

[1] Locations should be referenced to a map using Outfall and Subarea numbers.
[2] Combined sewer, storm sewer, or unsewered.
[3] Swirl separator or conventional regulator.

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TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 2 Pollutant Parameters (BOD_5, TSS, TC, P, N).

Segment No.	Pollutant Parameter	Required % Reduction
3	TSS TC	65% 95%
4	TSS TC	39% 99.8%

Note: This information is the same as that in Item 2 of COLLECTION SYSTEM CONTROL METHODOLOGY Illustrative Example Worksheet, page 92.

Item 3 Results of collection system controls.

i. Quantity of design storm runoff volume stored in internal storage of collection system 0.8 mg. (from page 92)

ii. Remaining runoff volumes and load:

Volume: 6 mg.
Flow: 6.3 mgd. (peak)
Load: _____ mg/l BOD_5
340 mg/l TSS
_____ mg/l P
_____ mg/l N
_____ #/100 ml

Note: Volume and flow can be determined from the overflow hydrograph. Loads are determined using the load assessment techniques in Chapters 2 and 3, modified by control alternatives previously evaluated, e.g., land management or collection system controls

Note: Collection system controls do not satisfy the load reduction requirements; therefore, other feasible control options were investigated. Table 6-10 was used to identify other options. Control option 5 will be evaluated for illustration purposes.

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TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 4 i. Cost of Regulator, from information in Appendix G, or equivalent method.

Construction Cost $ _____

O&M Cost $ _____

Total Present-Worth Cost $ _____
(using PRESENT-WORTH METHODOLOGY)

Note: Not applicable since swirl separator is to be used.

ii. Cost of swirl separator, using Table 6-11, or equivalent method.

Design flow 50 mgd (assumed for illustrative purposes

Construction Cost $ 30,500 (amortized - see Table 6-11)

O&M Cost $ 9,000

Total Present-Worth Cost $ 419,000
(using PRESENT-WORTH METHODOLOGY)

Item 5 Cost of storage tanks, from Table 6-11, or equivalent method.

Type of storage: Settling _____ Complete mix _____

Construction Cost $ _____

O&M Cost $ _____

Total Present-Worth Cost $ _____
(using PRESENT-WORTH METHODOLOGY)

Note: not applicable since treatment is to be provided. Item 6 will be used to determine the least-cost combination of storage and treatment.

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TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 6

i. Design Storm Characteristics.

Intensity _____ in/hour

Duration _____ hour

Frequency _____ /year

Note: The user can select the design storm based on an analysis of local rainfall/runoff characteristics, pollution reduction requirements and other factors, and can develop the inlet hydrograph using an applicable method of hischoice. For this illustration, the inlet hydrograph below is assumed.

ii. Inlet hydrograph(s) for design storm (storm runoff entering the sewer system).
Method (Assumed for illustrative purposes.)

Sub-area 1		Sub-area ___		Sub-area ___	
TIME (hr)	FLOW (mgd)	TIME	FLOW	TIME	FLOW
0	0				
0.5	0				
1.0	15				
1.5	40				
2.0	62.5				
2.5	60				
3.0	40				
3.5	21				
4.0	13				
4.5	8				
5.0	4.5				
5.5	2				
6.0	0				

NOTE: Plot hydrographs for each subarea on separate sheets of graph paper.

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TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 6 - Continued

iii. Inflow hydrograph to overflow control structure.

Routing Procedure _____

TIME		FLOW
Inlet	Inflow	
1.5	0	40
2	0.5	62.5
2.5	1.0	60
3.0	1.5	40
3.5	2.0	21
4.0	2.5	13
4.5	3.0	8
5.0	3.5	4.5
5.5	4.0	2
6.0	4.5	0

iv. Overflow hydrograph from the control structure.

(Attach rating curve for specific structure)

TIME	FLOW
Same coordinates as shown above	

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Illustrative Example Supplemental Notes

The user may use any applicable routing procedure to develop the inflow hydrograph to the overflow control structure. The routing procedure should take into account the use of in-line storage.

For this illustrative example, the volume retained by in-line storage (0.8 mg) is deleted from the hydrograph (shown by the shaded area on Plot A), and the actual inflow hydrograph begins at a time equal to 1.5 hours. The ordinates shown were taken from the inlet hydrograph plot.

The user can determine the overflow hydrograph using the inflow hydrograph and a rating curve for the particular overflow control device. For this illustrative example the overflow hydrograph is assumed to be the same as the inflow hydrograph to the control structure.

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PLOT A

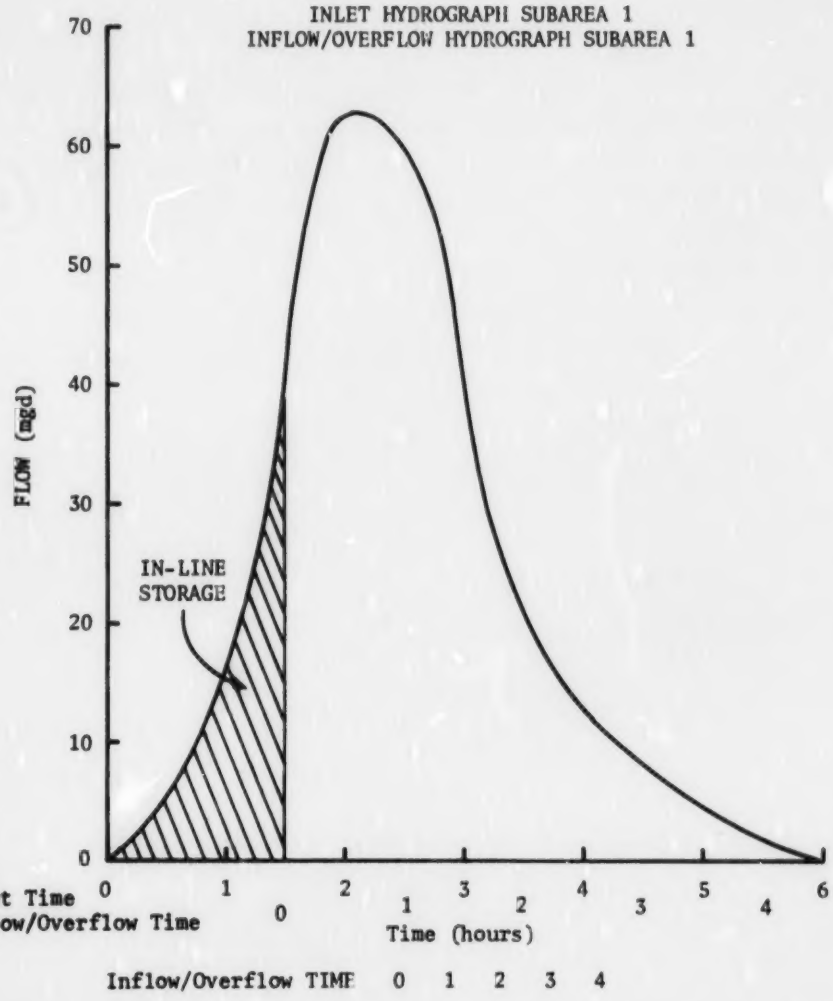

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TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 6 - Continued

Volume = area under hydrograph. For the illustrative example, trapezoidal approximations of areas were used.

v. Mass Curve from Overflow hydrograph.

TIME	INCREMENTAL VOLUME (mg)	CUMULATIVE VOLUME (mg)
0	0	0
0.1	0.18	0.18
0.2	0.22	0.4
0.3	0.24	0.64
0.4	0.26	0.9
0.5	0.28	1.18
0.75	0.69	1.87
1.00	0.67	2.54
1.5	1.17	3.71
2.0	0.61	4.32
2.5	0.35	4.67
3.0	0.32	4.99
4.0	0.2	5.09

NOTE: Plot Mass Curve on separate sheet of standard graph paper.

See Plot B

vi. Storage/Treatment requirements.

Using mass curve shown in Plot B

% MAXIMUM TREATMENT RATE	TREATMENT RATE mgd	STORAGE VOLUME mg
100	62.5	0
75	47	0.8
50	31	1.8
25	16	3.1
0	0	6.1

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PLOT B

MASS CURVE

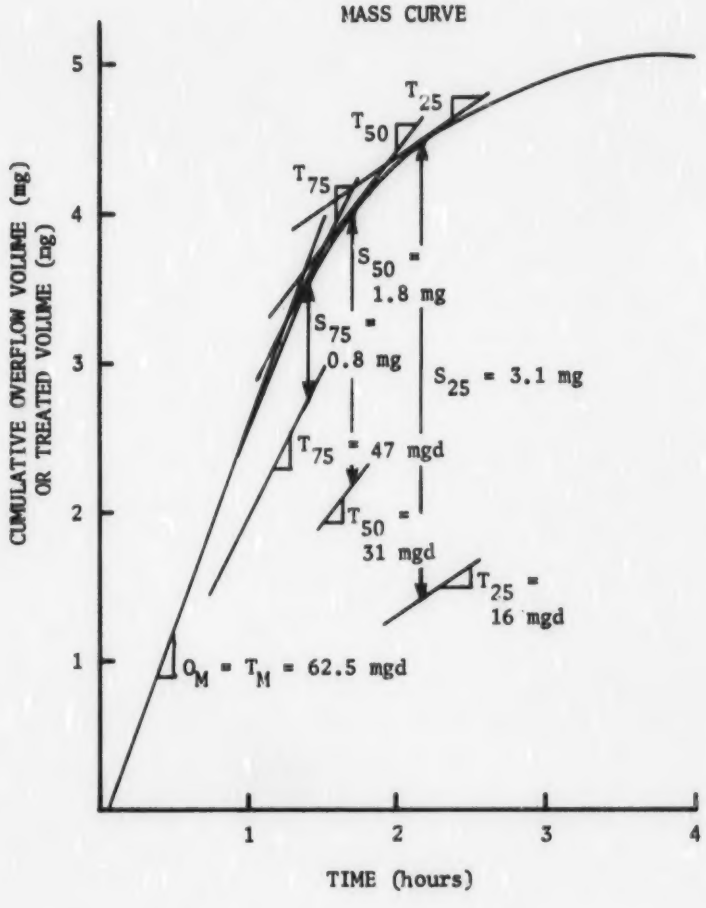

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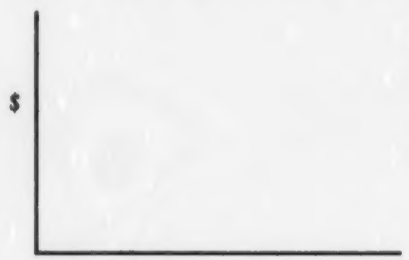
TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 6 - Continued

vii. Cost of storage, using cost functions from Table 6-11, or equivalent method, PRESENT-WORTH METHODOLOGY.
Type of storage High Density.

Volume to be Stored	Total Annual Cost ~~Construction Cost~~	O&M Cost	Present Worth Cost
0	0		0
0.8	40,800		432,000
1.8	91,800		973,000
3.1	158,000		1,676,000
5.1	260,000		2,757,000

NOTE: Plot Volume to be stored and Present Worth Cost.



Present worth costs obtained above are shown in Plot C.

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TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 6 - Continued

viii. Cost of on-site treatment, using cost functions from Table 6-11, or equivalent method, and PRESENT-WORTH METHODOLOGY.

Treatment Unit Microscreens

Treatment Rate	Construction Cost (amortized)	O&M Cost	Present Worth Cost
62.5	170,000	43,000	2,257,000
47	137,000	34,000	1,812,000
31	100,000	25,000	1,324,000
16	60,000	15,000	795,000

Treatment Unit Dissolved Air Flotation

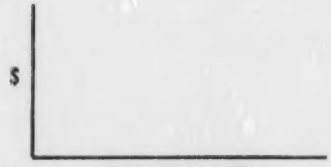
Treatment Rate	Construction Cost	O&M Cost	Present-Worth Cost
62.5	263,000	66,000	3,485,000
47	207,000	52,000	2,744,000
31	146,000	36,000	1,928,000
16	84,000	21,000	1,112,000

Treatment Unit _____

Treatment Rate	Construction Cost	O&M Cost	Present-Worth Cost

NOTE: Plot a cost curve for each type of treatment unit on the same set of axes.

See Plot C.



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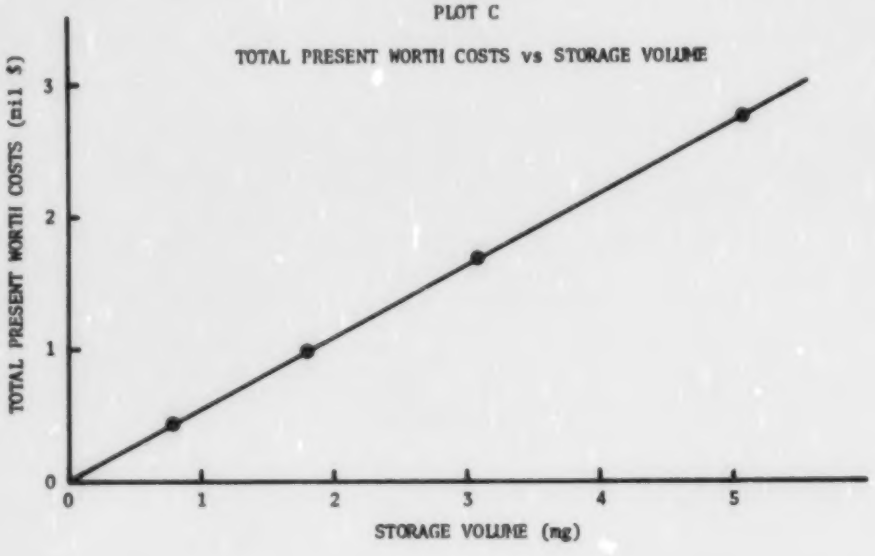
PLOT C

TOTAL PRESENT WORTH COSTS vs STORAGE VOLUME



TOTAL PRESENT WORTH COSTS vs TREATMENT RATE

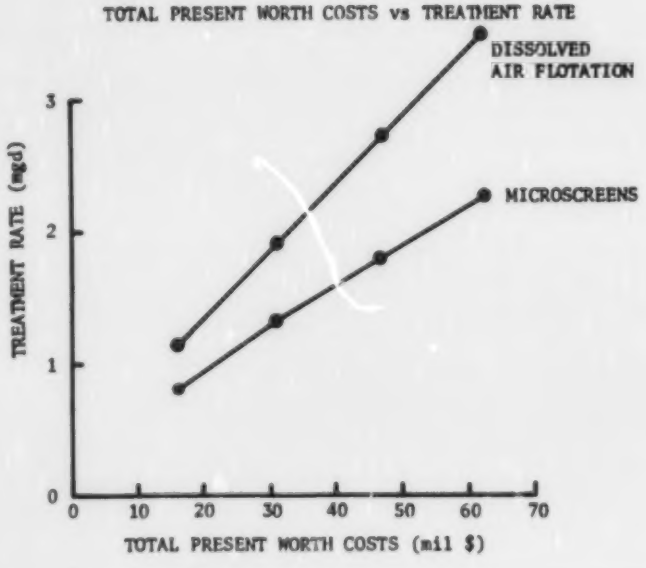


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TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 6 - Continued

Note: not applicable for this option.

ix. Cost of treatment at the existing plant.

a) Cost of discharging effluent to the interceptor and treating at existing plant.

i. If interceptor is adjacent to overflow control device (as in combined sewer), no cost is associated with discharge to the interceptor.

ii. If interceptor is not adjacent to the overflow control device, the cost to construct a sewer to transport the effluent can be determined using the TRANSPORTATION COST METHODOLOGY. PRESENT WORTH METHODOLOGY.

Flow to be Transported and Treated	Sewer Construction		Present Worth Cost
	Construction Cost	O&M Cost	

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TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 6 - Continued

Note: Not applicable for this option.

b) Costs of upgrading/expanding existing treatment facility using TREATMENT FACILITY METHODOLOGY and PRESENT-WORTH METHODOLOGY.

Treatment Rate	Construction Cost	O&M Cost	Present-Worth Cost

c) Total Present Worth cost of treatment at existing facility.

Treatment Rate	Total Present-Worth Cost of Transportation and Treatment

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TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 6 - Continued

x. Least-cost combination of storage and treatment.

Treatment Rate mgd	Least-cost Treatment Unit	Present-Worth Cost of Treatment	Storage Volume	Present-Worth Cost of Storage[1]	Total Present-Worth Cost
62.5	Microscreen	2,257,000	0	0	2,257,000
47	Microscreen	1,812,000	0.8	432,000	2,244,000
31	Microscreen	1,324,000	1.8	973,000	2,297,000
16	Microscreen	795,000	3.1	1,680,000	2,475,000
0	—	0	5.1	2,780,000	2,780,000

[1] Table 6-11 was used to generate storage costs. A storage for high density areas (15 people/acre) was selected.

NOTE: Plot total Present-Worth cost of storage and treatment versus treatment rate. See Plot D.

Least-cost combination of storage and treatment.

$ 2,200,000

Note: For an actual case, the user would utilize the above table to locate the approximate area of the minimum point, and then generate more treatment rate/present-worth cost combinations in order to more exactly locate the minimum cost combination. For this example, the minimum point is estimated to occur approximately at 47 mgd.

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PLOT D

TREATMENT RATE vs TOTAL PRESENT-WORTH COST

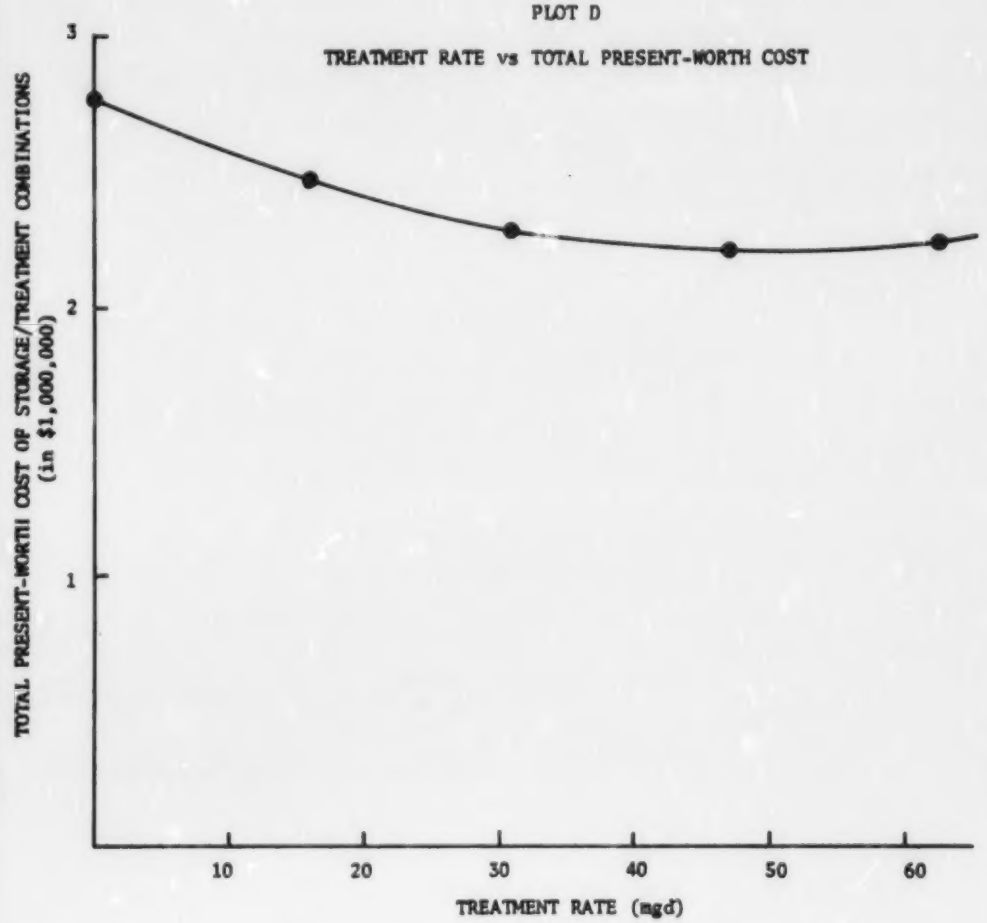

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TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 7

i. Cost of laying pipe to connect new regulator to existing outfall pipe (if significant), or cost of laying a new or larger outfall pipe, from cost curve in Appendix H, Figure H-84.

Construction Cost $ _____

O&M Cost $ _____

Not applicable for Option 5, Table 6-10.

Total Present Worth Cost $ _____
(using PRESENT WORTH METHODOLOGY)

ii. Cost of Disinfection (where required) from curve in Appendix H, Figure H-26.

Construction Cost $ 60,000

O&M Cost $ 1,100

Total Present Worth Cost $ 72,000
(using PRESENT WORTH METHODOLOGY)

Design Average Flow = 30 mgd (assumed for this example).

O+M cost is based on 60 days/year operation.

O+M Present Worth Cost = (O+M)(Present Worth Factor)

(1,100)(10.594)

= 11,600

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TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 8 Cost of sludge handling.

Not applicable for Option 5, Table 6-10

i. On-site sludge handling.
   a. Sludge treatment (using cost curves in Appendix H).
      1) Organic sludges

         Lime stabilization (Figure H-79)
           Construction Cost $ _____
           O&M Cost $ _____

         Vacuum Filtration (Figure H-68)
           Construction Cost $ _____
           O&M Cost $ _____

      2) Inorganic sludges

         Vacuum Filtration (Figure H-69)
           Construction Cost $ _____
           O&M Cost $ _____

      3) Subtotal $ _____

   b. Sludge transport (using cost curves in Appendix H, Figures H-86 through H-90).

      Method: _____
           Construction Cost $ _____
           O&M Cost $ _____

   c. Sludge disposal (using cost curves in Appendix H, Figures H-81 through H-83).

      Method: _____
           Construction Cost $ _____
           O&M Cost $ _____

   d. Total cost for on-site sludge handling.

           Construction Cost $ _____
           O&M Cost $ _____

   e. Total Present Worth Cost $ _____
      (using PRESENT WORTH METHODOLOGY)

ii. Sludge handling at existing wastewater treatment facility.
   a. Sludge transport to existing facility

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TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 8 - Continued

1) If sewer is storm sewer, determine cost to construct sewer to connect with sanitary sewer interceptor to treatment plant, using TRANSPORTATION COST METHODOLOGY.

Construction Cost $ _____
O&M Cost $ _____

2) If sewer is combined, existing interceptor capacity should be sufficient to transport sludges to the existing wastewater treatment plant.

b. Sludge treatment.

Determine if there is capacity available in existing sludge handling facilities to accept additional sludge volumes from the treatment of storm overflows. If not, determine cost to provide additional sludge handling capacity at the existing facility, using TREATMENT FACILITY METHODOLOGY.

Construction Cost $ _____
O&M Cost $ _____

c. Sludge disposal (using cost curves in Appendix H, Figures H-81, 82, or 83).

Method: _____
Construction Cost $ _____
O&M Cost $ _____

d. Total cost for sludge handling at existing wastewater treatment facilities.

Construction Cost $ _____
O&M Cost $ _____

e. Total Present Worth Cost $ _____
(using PRESENT WORTH METHODOLOGY)

Note: It is assumed for this example that there is existing capacity in the sludge handling facilities at the existing plant, and that no additional costs are incurred in transporting, treating, or disposing of the sludge from the sewer overflow treatment units (swirl separator and microscreen). In an actual case, the user might want to assign a cost for handling of this sludge, even though there is existing capacity at the plant, based on the relative proportion of total sludge volume which it represents.

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TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 9 Total Present Worth Cost.

Sewer Segment #1 Sewer Type Combined

i. For each storage/treatment option, record the Present-Worth costs of each component determined using Items 4-8.

ii. Determine the total Present Worth cost of each option.

Present Worth Cost (in $1,000)

Option #	Regulator	Swirl	Storage w/ Settling	Storage w/ mixing	On-site WW Treatment	Treatment at Existing Plant	Interceptor Construction	Disinfection	On-site Sludge Handling	Sludge Handling at Existing Plant	Total Present-Worth Cost
5	-	419	-	432	1,812	-	-	71	-	No Cost	2,734

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TABLE 6-9 (continued)
STORAGE/TREATMENT METHODOLOGY
WORKSHEET

Item 10 Regionalization of storage/treatment components, using REGIONALIZATION METHODOLOGY.

Components regionalized:

Regional Facility:

Construction Cost $ _____

O&M Cost $ _____

Present Worth Cost $ _____
(using PRESENT WORTH METHODOLOGY)

Not investigated for this example.

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Illustrative Example Supplemental Notes

The evaluation of control alternatives for wet weather sources also includes consideration of reuse. This utilizes the same component methodology as for dry weather sources; therefore, the worksheets are not included in this example. The differences in the evaluation procedure will typically include consideration of storage requirements and reuser reliability requirements.

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Illustrative Example Supplemental Notes

The potential for Impact Area Modifications to reduce the undesirable effects of wet weather sources is considered at this point in the load reduction strategy evaluation. The use of In-stream Reaeration and Low-Flow Augmentation are not relevant to the control of a wet weather source. However, Discharge Relocation is potentially viable. This evaluation would be identical to that for a dry weather source; therefore, the worksheets are not included here.

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Illustrative Example Supplemental Notes

The planner would generally continue the analysis of Load Reduction Strategy 9 at this point by considering for Source 4 the various control alternatives just described for Source 3. The user is referred to the previous worksheets for illustration of the appropriate methodologies.

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Checked by _____ Date _____ Source No. 4
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Illustrative Example Supplemental Notes

Following the evaluation of control alternatives for all sources identified in Load Reduction Strategy 9, the user would consider the effect of regionalized facilities on total project cost. The worksheets for this evaluation are not included for this example because all of the component methodologies have been previously utilized.

The evaluation of regional facilities for this example would include wet and dry weather sources. In addition, the residual disposal portion of the REGIONALIZATION METHODOLOGY would be useful in identifying effective alternatives.

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Remarks: _____ Page 124

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Illustrative Example Supplemental Notes

At this point, the user will have completed the development and evaluation of feasible control alternatives for the load reduction strategies of interest. The total monetary cost of each control alternative will have been developed and expressed as a Present-Worth cost. Also, a relative information reliability will have been determined for each control alternative.

The user is now ready to evaluate criteria other than monetary cost, such as implementability and environmental, social, and economic costs, in order to determine which load reduction strategy has the least total cost to society. This part of the evaluation leading to final selection is not covered by this manual. However, the monetary costs calculated using this manual are a major input to that determination.

By _____ Date _____ Strategy No. N/A
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Remarks: _____ Page 125

6.6 References

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8. Environmental Protection Agency, Urban Runoff Pollution Control Technology Overview, Field, R., Talfuri, A.N., and Masters, H.E., September, 1976.

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10. Environmental Protection Agency, Stormwater Management Model Level I - Preliminary Screening Procedures, EPA-600/2-76-275, October, 1976.

11. Environmental Protection Agency, Cost-Effectiveness Analysis of Municipal Wastewater Reuse, WPD-4-76-01, April, 1975.

12. Environmental Protection Agency, Guidance for Preparing a Facility Plan, revised May, 1975.

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18. Environmental Protection Agency, Cost-Effective Comparison of Land Application and Advanced Wastewater Treatment, Technical Report EPA-430/9-75-016, November, 1975.

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20. Grant, Eugene L. and W. Grant Ireson, Principles of Engineering Economy, Ronald Press, New York, 1970.

21. Environmental Protection Agency, Wastewater Sludge Utilization, Technical Report, EPA-430/9-75-015, September, 1975.

22. Environmental Protection Agency, Technical Bulletin on Municipal Sludge Management: Environmental Factors, soon to be published.

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APPENDIX D, PART II

PARAMETER HANDBOOK

This Parameter Handbook has been written as a part of the Areawide Assessment Procedures Manual to aid 208 planning agencies in the establishment and conduct of water quality monitoring programs. The material presented summarizes existing work rather than representing new research results. The intent is to present, on one sheet of paper, enough salient information about a particular water quality parameter to allow decisions to be made as to the likelihood of the constituent's presence in a particular stream or discharge, its effects upon water quality or use, and factors pertaining to sampling and analysis of the constituent that should be considered in determining the ramifications of including the parameter in a water quality monitoring program. The information presented on analytical methodology, including sample quantity and preservation and handling considerations, was largely taken from one of three widely available sources:

- *Methods for Chemical Analysis of Water and Wastes, 1974* (commonly called "EPA Methods Manual"). Available from USEPA Environmental Research Information Center, Cincinnati, OH 45268.

- *Standard Methods for the Examination of Water and Waste Water*, 14th Edition, 1976 (commonly called "Standard Methods"). Available from the American Public Health Association, 1015 18th Street, N.W., Washington, D.C. 20036.

- *Annual Book of Standards, Part 31, Water, 1975* (commonly called "ASTM Methods"). Available from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

The information presented herein was taken in the order indicated above, i.e., if the parameter is covered in the EPA Methods Manual, that reference was used as the primary source; if the parameter is not in the EPA Methods Manual but is covered by Standard Methods, the latter was used as the primary source; and so on. For parameters not treated by any of the above sources, other publications, especially those of the U.S. Geological Survey, were used.

It must be emphasized that this Parameter Handbook is not a specification; the information presented herein is illustrative, not exhaustive, and carries no legal authority. In this latter

regard, the USEPA has published, pursuant to section 304(g) of the Water Pollution Control Act Amendments (PL 92-500), "Guidelines Establishing Test Procedures for the Analysis of Pollutants" in the Wednesday, December 1, 1976 issue of the Federal Register (40 CFR 136), a copy of which is attached at the end of this Parameter Handbook. Some minor corrections to these Guidelines were published in the Federal Register on Tuesday, January 18, 1977.

The synoptic presentations in this Parameter Handbook are written for a reader without extensive training or experience in water and wastewater analysis. A common format, depicted in Figure 1, has been used for each parameter. The entries will be discussed in turn.

Parameter Name: This is the most common name by which the parameter is most frequently known, not necessarily its proper chemical name. Where other names are commonly used or the chemical formula might be helpful, they are indicated in the general discussion.

A number of parameters are part of the USEPA water quality data storage and retrieval system (STORET) at the present time, and more will be added in the future. Where a parameter is a part of the STORET System as of March 1977, the following two entries are filled in; otherwise they are left blank.

Parameter Group: Each parameter is assigned to a designated group (e.g., metals, general organic, pesticides) in the STORET System, and this entry indicates the group to which the parameter belongs.

STORET Units: The units that must be used for entry of the concentration of the parameter into the STORET System are given here; e.g., micrograms per liter ($\mu g/\ell$).

General: This is a brief summary of salient parameter characteristics. Typically covered are such things as what the parameter is; any common alternate name or chemical formula where possibly helpful; natural sources; uses of the substance and possible sources related thereto; indications of the persistence of the parameter in water, including its solubility where appropriate; effects of the parameter on water use, including toxicity data where appropriate; and, since many of these parameters are actually toxic substances or surrogate measures for toxic substances, the level of regulation that has been imposed upon them (such as the two technologically feasible control oriented standards of "best practicable control technology currently available" (BPT) or "best available control technology economically achievable" (BAT) or "toxicity effluent limitations") has been noted in accordance with the regulation (40 CFR 136), BAT parameters under the Consent Decree, or toxicity guidelines under the Consent Decree or other regulatory mandates.

PARAMETER NAME

Parameter Group: STORET Units:

General:

Criterion:

Preservation Method:

Maximum Holding Time:

Container Type:

Sample Volume Required:

Measurement:

Precision and Accuracy:

Cost of Analysis:

Figure 1. Format for Parameter Information

Criteria: If the USEPA has issued water quality criteria for the parameter, they are given here along with the beneficial use to be protected by the criterion established.

Preservation Method: Physical and chemical preservatives to be used to help maintain sample integrity are indicated here along with any special sample handling considerations, e.g., keep sealed until analyzed.

Maximum Holding Time: The maximum holding time between gathering and preserving the sample and its analysis in the laboratory is given here. It is a function not only of the physical and chemical characteristics of the substance involved but also of the other constituents in the sample. The holding times given are conservative in some instances and, if data indicate that longer holding times do not significantly affect analytical results, they may be used.

Container Type: Acceptable sample container materials are indicated here. Although not addressed here, sample equipment cleaning is very important, and special cleaning protocols will be required for some parameters, e.g., pesticides, as will other special considerations such as the use of TFE fluorocarbon cap liners, etc.

Sample Volume Required: An estimate of the quantity of sample necessary to allow analysis for the parameter is given here. No allowance for replication, sample splitting, spillage, etc., is made. The exact sample quantity required will depend upon the strength of the constituent, the need for concentration or dilution, removal of interferences, etc., and is best established after preliminary laboratory work, but the given volumes can be used as a first cut.

Measurement: Descriptions of common methods for making the determination are given here, primarily to indicate any special laboratory equipment that might be required (e.g., AA, GC). Applicable concentration ranges are given, and possible interferences and precautions are indicated in many cases. Where a measurement is mandated by regulation, the regulation is cited.

Precision and Accuracy: Method sensitivity and detection limits are provided where generally agreed to. Precision and accuracy data are given where known.

Cost of Analysis: The information provided here is intended to give an appreciation of the relative magnitude of cost for performing the analysis. The data are typically presented as a range that represents differences in cost among laboratories and (sometimes) methods for a given parameter. Cost information was obtained from various laboratories across the United States and

representative values were selected for the range. Extremely low or high costs for a particular parameter from a given laboratory were discarded as atypical. Costs are also influenced by sample preparation procedures necessary to remove interferences. This is especially true for pesticide analyses and is represented by large ranges in many instances, with the lower end of the range being more typical in most cases. Finally, although not indicated in the cost data presented herein, many laboratories offer quantity discounts that may be quite substantial, and local laboratories should be consulted if firm budget numbers are desired.

There are many water quality parameters that might be of interest to some 208 agencies. Those that were selected for inclusion in this first edition of the Parameter Handbook are the ones that were considered to have the broadest appeal. They represent a compilation of those found in the newly issued EPA Water Quality Criteria, the EPA Methods Manual, and the majority of the substances listed in the Consent Decree. It is contemplated that the parameter coverage will be increased in future editions of this handbook. For many parameters, preferred analytical methods, preservation techniques, maximum holding times, etc., have not been established or are tentative. Considerable advancement is expected in the near term time frame, and future editions will be updated to disseminate this information.

To assist the reader in locating parameters of interest, a number of tables are provided. In Table 1, all the parameters in the handbook are listed in alphabetical order. The parameters are alphabetically listed within each STORET parameter group in Table 2. Those parameters for which the USEPA has issued water quality criteria are alphabetically listed in Table 3. Finally, those parameters designated by the Consent Decree are listed alphabetically in Table 4. The parameter sheets in the handbook are in alphabetical order. A copy of the 1 December 1976 Federal Register is attached at the end.

TABLE 1. ALPHABETICAL LISTING OF PARAMETERS

Acidity
Acrolein
Acrylonitrile
Aldrin
Alkalinity
Aluminum
Antimony
Arsenic
Asbestos
Atrazine

Barium
Benzene
Benzene Hexachloride (BHC)
Benzidine
Beryllium
Biochemical Oxygen Demand (BOD)
Boron
Bromide

Cadmium
Calcium
Captan
Carbaryl
Carbon Tetrachloride
Chemical Oxygen Demand
Chlordane
Chloride
Chlorinated Benzenes
Chlorinated Ethanes
Chlorinated Naphthalene
Chlorinated Phenols (Other)
Chlorine Demand
Chlorine Dioxide
Chlorine, Residual
Chloroalkyl Ethers
Chloroform
2-Chlorophenol
Chromium
Cobalt
Color
Copper
Cyanide

2, 4-D
DD
DDE
DDT
Demeton
Diazinon
Dichlorobenzenes
Dichlorobenzidine
Dichloroethylenes
2, 4-Dichlorophenol
Dichloropropane
Dichloropropene
Dieldrin
2, 4-Dimethylphenol
Dissolved Oxygen
Disyston
Diuron

Endosulfan
Endrin
Ethylbenzene

Fecal Coliform
Fecal Streptococci
Fluoride

Guthion

Haloethers
Halomethanes
Hardness, Total
Heptachlor

Iodine
Iron

Lead
Lindane
Lithium

Magnesium
Malathion
Manganese

TABLE 1. ALPHABETICAL LISTING OF PARAMETERS (Cont'd)

Mercury
Methane
Methoxychlor
Methyl Parathion
Methylene Blue Active Substances (MBAS)
Mirex
Molybdenum

Naphthalene
Nickel
Nitrilotriacetic Acid (NTA)
Nitrobenzene
Nitrogen-Ammonia
Nitrogen, Kjeldahl
Nitrogen, Nitrate
Nitrogen, Nitrate-Nitrite
Nitrogen, Nitrite
Nitrophenols

Oil and Grease
Organic Carbon

Parathion
PCNB
Pentachlorophenol
pH
Phenolics
Phosphorous (all forms)
Phthalate Esters
Polychlorinated Biphenyls
Polynuclear Aromatic Hydrocarbons
Potassium

Radioactivity (alpha and beta)
Radium
Residue, Settleable
Residue, Total
Residue, Total Filterable
Residue, Total Nonfilterable
Residue, Volatile

Selenium
Silica
Silicon
Silver
Silvex (2, 4, 5-TP)
Sodium
Specific Conductance
Strontium
Sulfate
Sulfide
Sulfite

2, 4, 5-T
Temperature
Thallium
Threshold Odor
Tin
Titanium
Toluene
Total Coliform
Toxaphene
Trichloroethylene
Turbidity

Uranium

Vandaium
Vinyl Chloride

Xylene

Zinc

TABLE 2. LISTING OF PARAMETERS ACCORDING TO STORET GROUP

Bacteriologic

Fecal Coliform
Fecal Streptococci
Total Coliform

Dissolved Oxygen

Dissolved Oxygen

General Organic

Benzene
Methylene Blue Active Substances (MBAS)
Nitrilotriacetic Acid (NTA)
Oil and Grease
Organic Carbon
Phenolics
Phthalate Esters
Polychlorinated Biphenyls
Toluene
Xylene

General Inorganic

Acidity
Alkalinity
Asbestos
Bromide
Chloride
Chlorine Demand
Cyanide
Fluoride
Hardness, Total
Iodide
Sulfate
Sulfide
Sulfite

Metals

Aluminum
Antimony
Arsenic
Barium
Beryllium
Boron
Cadmium
Calcium
Chromium
Cobalt
Copper
Iron
Lead
Lithium
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Potassium
Selenium
Silver
Sodium
Thallium
Tin
Titanium
Uranium
Vanadium
Zinc

Miscellaneous

Chlorine, Residual

TABLE 2. LISTING OF PARAMETERS ACCORDING TO STORET GROUP (Cont'd)

Nitrogen

Nitrogen-Ammonia
Nitrogen, Kjeldahl
Nitrogen, Nitrate
Nitrogen, Nitrate-Nitrite
Nitrogen, Nitrite

Oxygen Demand

Biochemical Oxygen Demand (BOD)
Chemical Oxygen Demand

Pesticides

Aldrin
Atrazine
Benzene Hexachloride (BHC)
Benzidine
Captan
Carbaryl
Carbon Tetrachloride
Chlordane
Chloroform
2, 4-D
DDD
DDE
DDT
Demeton
Diazinon
Dieldrin
Disyston
Diuron
Endosulfan
Endrin
Guthion
Heptachlor
Lindane
Malathion
Methoxychlor
Methyl Parathion
Mirex
Parathion
Pentachlorophenol
Silvex (2, 4, 5-TP)
2, 4, 5-T
Toxaphene

Phosphorous

Phosphorus (all forms)

Physical

Color
PH
Specific Conductance
Threshold Odor
Turbidity

Radiological

Radioactivity (alpha and beta)
Strontium

Solids

Residue, Settleable
Residue, Total
Residue, Total Filterable
Residue, Total Nonfilterable
Residue, Volatile
Silica
Silicon

Temperature

Temperature

TABLE 3. PARAMETERS FOR WHICH THE USEPA HAS ISSUED WATER QUALITY CRITERIA

Aldrin	Lead
Alkalinity	Lindane
Arsenic	Malathion
Barium	Manganese
Beryllium	Mercury
Boron	Methoxychlor
Cadmium	Mirex
Chlordane	Nickel
Chlorine, Residual	Oil and Grease
Chromium	Parathion
Color	pH
Copper	Phenolics
Cyanide	Phosphorus (all forms)
2,4-D	Phthalate Esters
DDT	Polychlorinated Biphenyls
Demeton	Residue, Total Filterable
Dieldrin	Residue, Total Nonfilterable
Dissolved Oxygen	Selenium
Endosulfan	Silver
Endrin	Silvex
Guthion	Temperature
Heptachlor	Toxaphene
Iron	Zinc

TABLE 4. CHEMICAL CLASSES AND COMPOUNDS DESIGNATED AS PRIORITY POLLUTANTS IN THE TOXICS SETTLEMENT AGREEMENT

Acenaphthene
Acrolein
Acrylonitrile
Aldrin
Antimony (total)
Arsenic (total)
Asbestos
Benzene
Benzidine
Beryllium (total)
Cadmium (total)
Carbon Tetrachloride (tetrachloromethane)
Chlordane (technical mixture and metabolites)
Chlorinated Benzenes (other than dichlorobenzenes)
Chlorinated Ethanes (including 1, 2-trichloroethane and hexachloroethane)
Chlorinated Naphthalene
Chlorinated Phenols, (other than those listed elsewhere; includes trichlorophenols and chlorinated cresols)
Chloroalkyl Ethers (chloromethyl, chloroethyl, and mixed ethers)
Chloroform (trichloromethane)
2-Chlorophenol
Chromium (total)
Copper (total)
Cyanide (total)
DDT and Metabolites
Dichlorobenzenes
Dichlorobenzidine
Dichloroethylenes (1, 1-dichloroethylene and 1, 2-dichloroethylene)
2, 4-Dichlorophenol
Dichloropropane and Dichloropropene
2, 4-Dimethylphenol
2, 4-Dinitrophenol
Dinitrotoluene
1, 2-Diphenlhydrazine
Endosulfan and Metabolites
Endrin and Metabolites
Ethylbenzene
Fluroanthene
Haloethers (other than those listed elsewhere)
Halomethanes (other than those listed elsewhere)
Heptachlor and Metabolites
Hexachlorobutadiene
Hexachlorocyclohexane (all isomers)
Hexachlorocyclopentadiene
Isophorone
Lead (total)
Mercury
Naphthalene
Nickel (total)
Nitrobenzene
Nitrophenols (including 2, 4-dinitrophenol and dinitrocresol)
Nitrosamines
Pentachlorophenol
Phenol
Phthalate Esters
Polychlorinated Biphenyls (PCB's)
Polynuclear Aromatic Hydrocarbons
Selenium (total)
Silver (total)
2, 3, 7, 8-Tetrachlorodibenzo-P-Dioxin (TCDD)
Tetrachloroethylene
Thallium (total)
Toluene
Toxaphene
Trichloroethylene
Vinyl Chloride (chloroethylene)
Zinc (total)

ACIDITY

Parameter Group: General
Inorganic

STORET Units: mg/ℓ as $CaCO_3$

General: Acidity is a measure of a gross property of water, its quantitative ability to neutralize a strong base to a designated pH. It can be interpreted in terms of specific substances only when the chemical composition of the sample is known. Acids contribute to corrosiveness and influence certain chemical and biological processes; therefore, the acidity of water is important. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as practicable. Fill sample bottles completely and cap tightly. The sample should not be agitated or exposed to air for a prolonged period of time. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 100 mℓ

Measurement: The pH of the sample is determined and a measured amount of standard acid is added, as needed, to lower the pH to 4 or less. Hydrogen peroxide is added, the solution boiled for several minutes, cooled, and titrated electrometrically with standard alkali to pH 8.2. Suspended matter present in the sample, or precipitates formed during the titration may cause a sluggish electrode response. This may be offset by allowing a 15-20 second pause between additions of titrant or by slow dropping addition of titrant as the endpoint pH is approached. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: On a round robin conducted by ASTM on 4 acid mine waters, including concentrations up to 2,000 mg/ℓ, the precision was found to be ±10 mg/ℓ.

Cost of Analysis: $4 - $5

1000<

ACROLEIN

Parameter Group: STORET Units:

General: Acrolein (also known as acrylic aldehyde or 2-propenol) is a clear, colorless liquid at ordinary temperatures with a pungent irritating odor. It is extremely irritating to the skin and mucous membranes and is readily soluble in water. Its main use is as an aquatic weed killer. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Sample history must be known before any chemical or physical preservation steps can be applied to protect against separation. Fill the sample bottle completely and seal until analysis is performed. Do not refrigerate.

Maximum Holding Time: Unknown; preferably analyze within 1 hour.

Container Type: Borosilicate glass

Sample Volume Required: In excess of 200 mℓ

Measurement: No standard procedures for acrolein have been developed. It may require special treatment to extract from water prior to gas chromatographic analysis. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Precision and accuracy data are not available.

Cost of Analysis: Expensive; must be quoted based on sample composition.

1001<

ACRYLONITRILE

Parameter Group: STORET Units:

General: Acrylonitrile is a flammable liquid used in the manufacture of synthetic rubber and plastics and as a pesticide fumigant for stored grain. It is moderately soluble in water and does not disassociate markedly. Upon disassociation it can form HCN, the toxic cyanide principle. Concentrations of 20 mg/ℓ are deleterious for many fish. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Sample history must be known before any chemical or physical preservation steps can be applied to protect against phase separation. Fill the sample bottle completely and seal until analysis is performed. Do not refrigerate.

Maximum Holding Time: Unknown; preferably analyze within 1 hour.

Container Type: Borosilicate glass

Sample Volume Required: In excess of 200 mℓ

Measurement: No preferred method has been established. Acrylonitrile has been determined in wastewater by azeotropic distillation with methanol followed by measurement of NH_3 liberated by alkali saponification, but the method may not be practicable for many wastewaters. Detection limits are around 2,000 µg/ℓ. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Precision and accuracy data are not available.

Cost of Analysis: Expensive; must be quoted based on sample composition.

1002<

ALDRIN

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Aldrin, the common name of an organochlorine insecticide, is metabolically converted to dieldrin by aquatic organisms. Because of this metabolic conversion and because of evidence that dieldrin is as toxic or slightly more toxic than aldrin to aquatic organisms, an acceptable water concentration is based on the presence of either aldrin or dieldrin or the sum of both. Aldrin is used agriculturally at rates varying from 2 oz to 6 lb per acre, usually as a dust or emulsifiable concentrate; it is virtually insoluble in water. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants. A toxic effluent limitation has been prescribed for this parameter by the NPDES permits program.

Criteria

- 003 µg/ℓ for freshwater and marine aquatic life
- The persistence, bioaccumulation potential, and carcinogenicity of aldrin cautions human exposure to a minimum.

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for aldrin. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 µg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration. For example, at the 0.015 and 0.110 µg/ℓ concentrations, recoveries were around 69% and 72% and precisions were 47% and 41%, respectively.

Cost of Analysis: $30 - $150, depending upon preparation required.

1003<

ALKALINITY

Parameter Group: General
Inorganic

STORET Units: mg/ℓ as $CaCO_3$

General: Alkalinity is a measure of a gross property of water, its quantitative ability to neutralize a strong acid to a designated pH. It can be interpreted in terms of specific substances only when the chemical composition of the sample is known. Alkalinity, therefore, is a measure of the buffering capacity of the water, and since pH has a direct effect on organisms as well as an indirect effect on the toxicity of certain other pollutants in the water, the buffering capacity is important to water quality. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 20 mg/ℓ or more as $CaCO_3$ for freshwater aquatic life except where natural concentrations are less.

Preservation Method: Analyze as soon as practicable. Fill sample bottles completely and cap tightly. The sample should not be agitated or exposed to air for a prolonged period of time. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 100 mℓ

Measurement: An unaltered sample is titrated to an electrometrically determined end point of pH 4.5. The sample must not be filtered, diluted, concentrated, or otherwise altered in any way. Substances such as salts of weak organic and inorganic acids present in large amounts may cause interference in the electrometric pH measurements. Oil and grease may interfere by coating the electrode, thereby causing sluggish response. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: No general statement can be made about precision due to the great variation in sample characteristics. Forty analysts in seventeen laboratories analyzed synthetic water samples containing increments of bicarbonate equivalent to around 9 and 116 mg/ℓ $CaCO_3$. The bias was approximately +16% and -8% and relative standard deviation was approximately 14% and 5%, respectively.

Cost of Analysis: $4 - $5

1004<

ALUMINUM

Parameter Group: Metals STORET Units: µg/ℓ as Al

General: Aluminum, being the third most abundant element in the earth's crust, occurs in minerals, rocks, and clays. Aluminum is found as a soluble salt, a colloid, or an insoluble compound in natural waters. Aluminum in wastewaters occurs from primary aluminum production and from secondary aluminum processes such as ingot cooling and shot quenching, scrubbing of furnance fumes during demagging, and wet milling of residues. Washwater from water treatment plants is another likely source, as are discharges from dyeing and cloth printing operation, paper mills, disinfectant operation, tanneries, viscose rayon plants, and many other industrial operations. Very little ingested aluminum is absorbed in the alimentary canal, so its presence does not normally pose a public health problem. Conflicting literature abounds on crop effects. An average daily dose of 2 mg aluminum has not harmed rats. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 309.2 nm. Aluminum is partially ionized in the nitrous oxide-acetylene flame. This problem may be controlled by the addition of an alkali metal (potassium, 1,000 µg/mℓ) to both sample and standard solutions. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 1,000 µg/ℓ; its detection limit is 100 µg/ℓ. The optimum concentration range is 5,000-100,000 µg/ℓ. At a concentration of 300 µg/ℓ, the relative standard deviation is 22.2%, and the relative error is 0.7%. Precision and accuracy decrease markedly for decreasing concentrations. For example, in an interlaboratory study on trace metals analysis, at true values of 35 and 15 µg/ℓ, the relative standard deviations were 309% and 1,120%, respectively, while the relative errors were 175% and 627%, respectively.

Cost of Analysis: $10 - $20

1005<

ANTIMONY

Parameter Group: Metals STORET Units: µg/ℓ as Sb

General: Natural antimony occurs chiefly as the sulfide or in oxide forms. Antimony is used in various industrial operations, especially in alloying as, for example, with lead for storage battery plates, with lead and tin in type metals, and with tin and copper as a bearing or antifriction material, and may be introduced into wastewaters from such sources, as well as the rubber, textile, explosives, paint, ceramic, and glass industries. Antimony has been reported to cause dermatitus and gastrointestinal disturbances in humans (it has long been used as an emetic) and has been found to shorten the life span of rats. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 217.6 nm. In the presence of lead (1,000 mg/ℓ), a spectral interference may occur at the 217.6 nm resonance line. In this case, the 231.1 nm antimony line should be used. Increasing acid concentrations decrease antimony absorption. To avoid this effect, the acid concentration in the samples and in the standards should be matched. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 500 µg/ℓ; its detection limit is 200 µg/ℓ. The optimum concentration range is 1,000-40,000 µg/ℓ. In a single laboratory, using a mixed industrial-domestic waste effluent at concentrations of 5,000 µg and 15,000 µg Sb/ℓ, the relative standard deviations were 1.6% and .66%, respectively. Recoveries at these levels were 96% and 97%, respectively.

Cost of Analysis: $10 - $20

1006<
ARSENIC

Parameter Group: Metals STORET Units: µg/ℓ as As

General: Mineral dissolution, industrial discharges, or the application of pesticides may lead to the occurrence of arsenic in water. Though most forms of arsenic are toxic to humans, arsenicals have been used in the medical treatment of spirochaetal infections, blood dyscrasias and dermatitis. Arsenic and arsenicals have many diversified industrial uses such as hardening of copper and lead alloys, tannery operations, pigmentation in paints and fireworks, and the manufacture of glass and ceramics, cloth, electrical semiconductors, and petroleum products. Arsenicals are used in the formulation of herbicides for forest management and agriculture. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criteria:

- 50 µg/ℓ for domestic water supplies (health)
- 100 µg/ℓ for irrigation of crops

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric gaseous hydride method is recommended for determining total arsenic, using a wavelength of 193.7 nm. The method is applicable to most fresh and saline waters in the absence of high concentrations of chromium, copper, cobalt, mercury, molybdenum, nickel, and silver. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is approximately 2.5 µg/ℓ; its detection limit is 2.0 µg/ℓ. The working range of the method is 2.0-20 µg/ℓ. At a concentration of 10 µg/ℓ, the relative standard deviation is 6% and the relative error is 1%. Ten replicate solutions of o-arsenilic acid at the 5, 10, and 20 µg/ℓ level were analyzed by a single laboratory. Relative standard deviations were 6%, 9%, and 5.5% with recoveries of 94, 93, and 85%, respectively.

Cost of Analysis: $15 - $20

1007<

ASBESTOS

Parameter Group: General Inorganic

STORET Units: Count/liter with length/width >1

General: Asbestos is primarily an air pollutant which has been shown to produce asbestosis, lung cancer, and mesothelioma in asbestos workers. However, the problems of asbestos in water have been recognized. It was discovered in 1973 that the drinking water of Duluth, Minnesota, and other cities on Lake Superior was heavily contaminated with asbestos. Sources of asbestos contamination include: asbestos mining, pulpmills, asbestos products, installation of asbestos construction material, spray-on steel fireproofing, and insulating cement application. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Analyze as soon as possible

Maximum Holding Time: Unknown

Container Type: Glass or plastic

Sample Volume Required: Approximately 1,000 mℓ

Measurement: The present procedure is the microscopic counting of fibers in water. Asbestos probably cannot be routinely determined in effluents in the absence of gross contamination. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Precision and accuracy data are not available at this time.

Cost of Analysis: No standard pricing due to impracticability of analysis.

1008<

ATRAZINE

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Atrazine, 2-chloro-4-ethylamino-6-isopropylamino-S-triazine, is a triazine pesticide. It is used as a selective herbicide. It has an oral LD_{50} in rats of 3.08 g/kg. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 1,000 mℓ

Measurement: The recommended method covers the determination of various symmetrical triazine pesticides. It involves an efficient sample extraction procedure and provides, through use of column chromatography, a method for the elimination of non-pesticide interferences and the pre-separation of pesticide mixtures. Identification is made by selective gas chromatographic separation, and measurement is accomplished by the use of an electrolytic conductivity detector (CCD). Solvents, reagents, glassware, and other sample processing hardware may yield discrete artifacts and/or elevated baselines causing misinterpretation of gas chromatograms. The interferences in industrial effluents are high and varied. Nitrogen containing compounds other than the triazines may interfere. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Atrazine can be determined by this method with a sensitivity of 1 µg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $30 to $150, depending upon preparation required.

1009<

BARIUM

Parameter Group: Metals STORET Units: µg/ℓ as Ba

General: Barium compounds are used in a variety of industrial applications including the metallurgical, paint and dye, glass, ceramic, and electronics industries, as well as for medicinal purposes, the vulcanizing of rubber, and explosives manufacturing. Barium naturally occurs only in trace amounts in water. Therefore, appreciable amounts of barium indicates undesirable industrial discharges. A barium dose of 550,000 to 600,000 µg is considered fatal to human beings. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 1 mg/ℓ for domestic water supply (health)

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 553.6 nm. The use of a nitrous oxide-acetylene flame virtually eliminates chemical interference; however, barium is easily ionized in this flame and potassium must be added (1,000,000 µg/ℓ) to standards and samples alike to control this effect. If the nitrous oxide flame is not available and acetylene-air is used, phosphate, silicon and aluminum will severely depress the barium absorbance. This may be overcome by the addition of 2,000,000 µg/ℓ lanthanum. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 400 µg/ℓ; its detection limit is 30 µg/ℓ. The optimum concentration range is 1000-20,000 µg/ℓ. At a concentration of 500 µg/ℓ, the relative standard deviation is 10%, and the relative error is 8.6%. In a single laboratory, using a mixed industrial-domestic waste effluent at concentrations of 400 and 2,000 µg Ba/ℓ, the relative standard deviations were 10.8% and 6.5%, respectively. Recoveries at these levels were 94% and 113%, respectively.

Cost of Analysis: $10 - $15

1010<

BENZENE

Parameter Group: General Organic

STORET Units: µg/ℓ

General: Benzene (C_6H_6) is the simplest of the aromatic compounds and is used extensively as a commercial solvent and for the synthesis of other organic substances. At normal temperatures it is a volatile, flammable, colorless liquid with an ethereal odor. It is moderately soluble in water, 820 mg/ℓ at 22°C. It occurs in wastes from chemical plants, dyeing and other textile operations, and many other industrial processes. The oral LD_{50} for rats is around 5,600 mg/kg of body weight. The toxicity of benzene toward fish has been reported from 5,000 µg/ℓ up to 395,000 µg/ℓ depending upon age and species. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Not determined. Analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 200-1,000 mℓ

Measurement: Hexadecone extraction followed by a gas chromatographic and mass spectrometric analysis is often used. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Detection limits should be around 2-10 µg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $15 - $30

1011<

BENZENE HEXACHLORIDE (BHC)

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Benzene hexachloride (BHC), the common name of hexachlorocyclohexane, is an organochlorine pesticide. It has five known stereoisomers, the gamma isomer (lindane) being the most powerful insecticidal principle. BHC has a residual life in soil approaching that of DDT. Elevated concentrations of BHC reduce treatment plant efficiency, cause stream organisms to disappear, and produce disagreeable odors. It can impart a musty odor and taste to crops. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for BHC. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors but usually falls in the 0.001 to 1 µg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration.

Cost of Analysis: $30 - $150, depending upon preparation required.

1012<

BENZIDINE

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Benzidine (4, 4'-diaminobiphenyl, $C_{12}H_{12}N_2$) is a polynuclear organic pesticide. A crystalline substance, it is only slightly soluble in water. It possesses carcinogenic properties and must be handled with great care. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants. A toxic effluent limitation has been prescribed for this parameter by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 1 week

Container Type: Borosilicate glass

Sample Volume Required: 1,000-4,000 mℓ, depending on concentration and instrument used.

Measurement: Benzidines are separated and concentrated by multiple extractions and then oxidized by chloramine T. The oxidation product is extracted and measured spectrophotometrically. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The detection limit is approximately 0.2 µg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $20 - $40; because of its carcinogenic properties, special facilities may be required at greatly increased cost.

1013<

BERYLLIUM

Parameter Group: Metals STORET Units: µg/ℓ as Be

General: Beryllium is not likely to occur at significantly toxic levels in ambient natural waters. Beryllium could enter waters in effluents from certain metallurgical plants and discharges from industries dealing with atomic reactors, X-ray diffraction tubes, neon signs, aircraft and rockets, and missile fuel. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criteria:

- 11 µg/ℓ for the protection of aquatic life in soft fresh water
- 1,100 µg/ℓ for the protection of aquatic life in hard fresh water
- 100 µg/ℓ for continuous irrigation on all soils; except
- 500 µg/ℓ for irrigation on neutral to alkaline fine-textured soils

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric or aluminum colorimetric methods are suitable. The latter requires either a spectrophotometer for use at 515 nm or a filter photometer equipped with a green filter having maximum transmittance near 515 nm; either must provide a light path of 5 cm. Sodium and silicon at concentrations in excess of 1,000,000 µg/ℓ have been found to severely depress the beryllium absorbance. Bicarbonate ion is reported to interfere; however, its effect is eliminated when samples are acidified to a pH of 1.5. Aluminum at concentrations of >500 µg/ℓ is reported to depress the sensitivity of beryllium. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 25 µg/ℓ; its detection limit is 5 µg/ℓ. The optimum concentration range is 50-2,000 µg/ℓ. In a single laboratory, using a mixed industrial-domestic waste effluent at concentrations of 10, 50, and 250 µg/ℓ, the relative standard deviations were 10%, 2%, and 1%, respectively. Recoveries at these levels were 100%, 98%, and 97%, respectively. In 32 laboratories using a known sample containing 250 µg/ℓ, the beryllium was determined colorimetrically with a relative standard deviation of 7% and a relative error of 12%.

Cost of Analysis: $10 - $20

1015<

BIOCHEMICAL OXYGEN DEMAND (BOD)

Parameter Group: Oxygen Demand STORET Units: mg/ℓ

General: The biochemical oxygen demand (BOD) determination is an empirical test used to obtain a measure of the relative oxygen demand of water, especially treatment plant loadings and removal efficiencies. It is important to realize that BOD results cannot be compared unless the results have been obtained under identical test conditions and that the test is of limited value in determining the actual oxygen demand of surface waters. Complete stabilization of a given sample may require a period of incubation too long for practicable purposes, so the 5-day test is most commonly reported. As an indicator parameter, BOD is not a pollutant and exercises no direct harm. Its indirect effect is to depress dissolved oxygen levels. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 6 hours

Container Type: Plastic or glass

Sample Volume Required: 1000 mℓ

Measurement: The recommended method is an empirical bioassay type procedure which measures the dissolved oxygen consumed by microbial life while assimilating and oxidizing the organic matter present. The standard test conditions include dark incubation at 20°C for 5 days. The determination of dissolved oxygen may be made by use of either the modified Winkler or the electrode method. Many samples will require seeding due to low microbal populations. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Eighty-six analysts in fifty-eight laboratories analyzed natural water samples plus an exact increment of biodegradable organic compounds. At mean values of 2.1 and 175 mg/ℓ BOD, the standard deviations were ±0.7 and ±26 mg/ℓ, respectively. There is no acceptable procedure for determining the accuracy of the BOD test.

Cost of Analysis: $10 - $17

1016<

BORON

Parameter Group: Metals STORET Units: µg/ℓ as B

General: Boron is usually found in nature as a sodium or calcium borate salt. A major source of boron in domestic wastewater is sodium perborate, used as a bleach in household washing powders. Fluoroborate solutions are used for plating of cadmium, copper, lead, nickel, tin, and zinc. Boron salts are used in fire retardants, the production of glass, leather tanning and finishing industries, cosmetics, photographic materials, metallurgy, and for high energy rocket fuels. The ingestion of excessive doses of borates may cause nausea, cramps, convulsions, coma, or other symptoms of distress. It appears to pose a greater hazard to plants than humans, however. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 750 µg/ℓ for long-term irrigation on sensitive crops

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Polyethylene bottles or alkali-resistant, boron-free glassware.

Sample Volume Required: 50-200 mℓ

Measurement: The curcumin method using colorimetric equipment is recommended for concentrations in the 100 to 1,000 µg/ℓ range. When a sample of water containing boron is acidified and evaporated in the presence of curcumin, a red-colored product called rosocyanine is formed. The rosocyanine is taken up in a suitable solvent, and the red color is compared with standards either visually or photometrically. One of the following equipments will be required: (a) spectrophotometer for use at 540 nm with a light path of 1 cm, or (b) a filter photometer equipped with a green filter having a maximum transmittance near 540 nm with a minimum light path of 1 cm. Nitrate nitrogen concentrations above 20,000 µg/ℓ interfere. Significantly high results are possible when the total of calcium and magnesium hardness exceeds 100,000 µg/ℓ as $CaCO_3$. Passing the sample through a cation exchange resin eliminates this problem. Close control of such variables as volumes and concentrations of reagents, as well as time and temperature of drying, must be exercised for maximum accuracy. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The minimum detectable quantity is 0.2 µg/ℓ B. A synthetic sample, containing 240 µg/ℓ B, 40 µg/ℓ As, 250 µg/ℓ Be, 20 µg/ℓ Se, and 6 µg/ℓ V in distilled water, was analyzed by the curcumin method in 30 laboratories with a relative standard deviation of 22.8% and a relative error of 0%.

Cost of Analysis: $5 - $20

1018<

BROMIDE

Parameter Group: General Inorganic

STORET Units: mg/ℓ as Br

General: Naturally occurring bromide in water is negligible, outside of coastal areas, the major sources being chemical industry and saltworks effluents. It is used for medicinal compounds, dyestuffs, gasoline additives, and swimming pool water sterilization. Like other halogens it is antiseptic and disinfectant and, hence, may possibly interfere with bacterial and other natural purification processes. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 100 mℓ

Measurement: The titrimetric method is recommended. The concentration range for this method is 2-20 mg bromide/ℓ. After pretreatment to remove interferences, the sample is divided into two aliquots. One aliquot is analyzed for iodide. The other aliquot is analyzed for iodide plus bromide. Bromide is then calculated by difference. Iron manganese and organic matter can interfere; however, the calcium oxide pretreatment removes or reduces these to insignificant concentrations. Color interferes with the observation of indicator and bromine - water color changes. This interference is eliminated by the use of a pH meter instead of a pH indicator and the use of standardized amounts of oxidant and oxidant quencher. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: In a single laboratory, using a mixed domestic and industrial waste effluent, at concentrations of 0.3, 2.8, 5.3, 10.3, and 20.3 mg/ℓ of bromide, the relative standard deviations were 43%, 13%, 7.2%, 4.3%, and 2.1%, respectively. At concentrations of 2.8, 5.3, 10.3, and 20.3 mg/ℓ of bromide, recoveries were 96%, 83%, 97%, and 99%, respectively.

Cost of Analysis: $15 - $20

1019<

CADMIUM

Parameter Group: Metals STORET Units: µg/ℓ as Cd

General: Cadmium occurs in nature chiefly as a sulfide salt, frequently in association with zinc and lead ores. The salts of the metal also may occur in wastes from electroplating plants, pigment works, textile and chemical industries. Cadmium is also used in everyday items such as paint, some pottery pigments, plastics, and automobile tires. Cadmium is present as an impurity in the more common galvanized coatings. Biologically, cadmium is a nonessential, nonbeneficial element recognized to be of high toxic potential. The concentration and not the absolute amount determines the acute toxicity of cadmium. Cadmium and cadmium compounds produce acute or chronic symptoms varying in intensity from irritations to extensive disturbances resulting in death. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criteria:

- 10 µg/ℓ for domestic water supply (health)
- Aquatic Life:

Fresh Water

Soft Water	Hard Water	
0.4 µg/ℓ	1.2 µg/ℓ	for cladocerans and salmonid fishes
4.0 µg/ℓ	12.0 µg/ℓ	for other, less sensitive, aquatic life

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 228.8 nm. For levels of cadmium below 20 µg/ℓ, the extraction procedure is recommended. The dithizone procedure may also be used. It requires either a spectrophotometer for use at 518 nm or a filter photometer equipped with a green filter having a maximum light transmittance near 518 nm; either must provide a light path of at least 1 cm. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 250 µg/ℓ; its detection limit is 2 µg/ℓ. The optimum concentration range is 50-2,000 µg/ℓ. At a concentration of 50 µg/ℓ, for the AA method the relative standard deviation is 21.6% and the relative error is 8.2%, while for the dithizone method they are 24.6% and 6.0%, respectively.

Cost of Analysis: $10 - $15

1021<

CALCIUM

Parameter Group: Metals STORET Units: mg/ℓ as Ca

General: Calcium enters water supplies through passage over deposits of limestone, dalomite, gypsum, and gypsiferous shale. Calcium salts and ions are among the most commonly encountered substances in water. Calcium salts breakdown on heating to form scale in boilers, pipes, and cooking utensils. Calcium adds to the total hardness of water. Calcium salts used on unpaved roadways and in innumerable industrial discharges represent other sources. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 422.7 nm. Phosphate, sulfate and aluminum interfere but are masked by the addition of lanthanum. The nitrous oxide-acetylene flame will provide two to five times greater sensitivity and freedom from chemical interferences. Ionization interferences should be controlled by adding a large amount of alkali to the sample and standards. For general use, the EDTA titrimetric method is the method of choice due to its simplicity and rapidity. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 0.08 mg/ℓ; its detection limit is 0.003 mg/ℓ. The optimum concentration range is 0.2-20 mg/ℓ. In a single laboratory, using distilled water at concentrations of 9.0 and 36 mg/ℓ, the relative standard deviations were 3.3% and 1.6%, respectively. Recoveries at both these levels were 99%. In a 44-laboratory test, synthetic unknown samples containing 108 mg/ℓ Ca (with other metals) were analyzed with a relative standard deviation of 9.2% and a relative error of 1.9%.

Cost of Analysis: $5 - $15

1022<

CAPTAN

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Captan is an approved name for the organochlorine fungicide $C_9H_8Cl_3NO_2S$. It is the active ingredient in the proprietary product Captan 50-W and was also known as SR-406, Vancide 89, and Orthocide. It is insoluble in water but partially soluble in some organic solvents. Captan has a very low toxicity to mammals (e.g., the LD_{50} for rats is over 9 g/kg of body weight) and is readily hydrolyzed, the effective residual life being on the order of two weeks. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for captan. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors but usually falls in the 0.001 to 1 µg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration.

Cost of Analysis: $30 - $150, depending upon preparation required.

1023<

CARBARYL

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Carbaryl, commonly known as Sevin, is an O-ARYL carbamate insecticide. It is commonly used on lawns as well as for other purposes. It is slightly soluble in water, sparingly soluble in most organic solvents, but freely soluble in amides. It has low mammalian toxicity, the acute oral LD_{50} to rats being reported from 500,000 to 2,190,000 µg/kg of body weight. Although persistent, its toxicity to aquatic life appears to be low also. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 1,000 mℓ

Measurement: In the recommended method, a measured volume of water is extracted with methylene chloride, and the concentrated extract is cleaned up with a Florisil column. Appropriate fractions from the column are concentrated and portions are separated by thin-layer chromatography. The carbamates are hydrolyzed on the layer and the hydrolysis products are reacted to yield specific colored products. Quantitative measurement is achieved by visually comparing the responses of sample extracts to the responses of standards on the same thin layer. Identifications are confirmed by changing the pH of the layer and observing color changes of the reaction products. Phenols interfere directly, and indirect interferences may be encountered from naturally colored materials whose presence masks the carbamate reaction. The method is recommended for use only by an experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Carbaryl can be determined with a sensitivity of 1 µg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $30 - $60

1024<

CARBON TETRACHLORIDE

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Carbon tetrachloride, CCl_4, is used in industry as an organic solvent, fire extinguisher, and for dry cleaning of clothing. In human and veterinary medicine, it is used as an antihelminthic. Carbon tetrachloride is colorless nonflammable liquid with a strong odor. Death has occurred from ingestion of 5 mℓ, about 8 grams. Repeated skin contact will result in dermatitis. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Sample history must be known before any chemical or physical preservation steps can be applied to protect the sample from phase separation. Fill the sample bottle completely and seal until analysis is performed. Do not refrigerate.

Maximum Holding Time: Unknown; preferably analyze within 1 hour.

Container Type: Borosilicate glass

Sample Volume Required: In excess of 200 mℓ

Measurement: The recommended method for carbon tetrachloride is a direct aqueous-injection procedure for the determination of gas chromatographable chlorinated hydrocarbons. A 3-10 µℓ aliquot of the sample is injected into the gas chromatograph equipped with a halogen specific detector. Compounds containing bromine or iodine will interfere with the determination. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Sensitivity of the method is approximately 1,000 µg/ℓ. Detection limits of 0.2-3 µg/ℓ may be achieved. Precision and accuracy data are not available at this time.

Cost of Analysis: Around $60.

1025<

CHEMICAL OXYGEN DEMAND

Parameter Group: Oxygen Demand STORET Units: mg/ℓ

General: The chemical oxygen demand (COD) test determines the quantity of oxygen required to oxidize a portion of organic matter in a waste sample, under specific conditions of oxidizing agent, temperature, and time. It is an important parameter for stream and industrial waste studies and control of waste treatment plants and can be rapidly determined. Exactly the same technique must be used each time, since the results depend upon the chemical oxidant used, the structure of the organic compounds, and the manipulative procedures. Although empirical correlations with other oxygen demand indicators may be made for a given waste stream, there is no uniform theoretical basis for association. COD is not a pollutant in and of itself and exercises no direct harm. Its indirect effect is to depress dissolved oxygen levels. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add H_2SO_4 to pH <2.

Maximum Holding Time: 7 days

Container Type: Plastic or glass

Sample Volume Required: 50 mℓ

Measurement: The dichromate reflux method is recommended. The method is applicable to domestic and industrial waste samples having an organic carbon concentration greater than 15 mg/ℓ. For lower concentrations of carbon such as in surface water samples, the low level modification should be used. When the chloride concentration of the sample exceeds 2,000 mg/ℓ, the modification for saline waters is required. To reduce loss of volatile organics, the flask should be cooled during addition of the sulfuric acid solution. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Eighty-six analysts in fifty-eight laboratories analyzed a distilled water solution containing oxidizable organic material equivalent to 270 mg/ℓ COD. The relative standard deviation was 6.6% and relative error was 4.7%. A set of synthetic unknowns analyzed by 74 laboratories resulted in a relative standard deviation of 6.5% at the 200 mg/ℓ COD level. At 160 mg/ℓ COD and 100 mg/ℓ chloride, the relative standard deviation was 10.8%.

Cost of Analysis: $10 - $17

1026<

CHLORDANE

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Chlordane, the common name of an organochlorine insecticide, is a highly persistent chemical which bioaccumulates in aquatic organisms used for human food. Technical grade chlordane is a mixture of toxic compounds that have not been separated in manufacture. There is an extremely wide range for the acute toxicity of chlordane to various species of freshwater fishes. Fishes can concentrate chlordane directly from water by a factor of 1,000 to 3,000 times, and invertebrates may concentrate to twice this magnitude. Chlordane is stable in the soil and is fungicidal. It could be contained in irrigation return flows. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criteria:

- 0.01 µg/ℓ for freshwater aquatic life
- 0.004 µg/ℓ for marine aquatic life
- The persistence, bioaccumulation potential, and carcinogenicity of chlordane cautions human exposure to a minimum.

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for chlordane under favorable conditions. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 µg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration.

Cost of Analysis: $30 - $150, depending upon preparation required.

1028<
CHLORIDE

Parameter Group: General
Inorganic

STORET Units: mg/ℓ as Cl

General: Chloride is one of the major inorganic anions in water arising from natural mineral origin, seawater intrusion, salts used for agricultural purposes, sewage, industrial effluents (including paperworks, galvanizing plants, water softening plants, oil wells, and petroleum refineries), roadway deicing, and other sources. Chlorides in drinking water are not normally harmful at palatable concentrations. It is generally the cation associated with the chloride that produces a harmful effect. Chloride ions exert a significant effect on the corrosion rate of metals (e.g., steel and aluminum) and are considered to be among the most troublesome anions in irrigation water. Injury to livestock seldom occurs below the 4,000 mg/ℓ level, but injury to fish has been reported at 400 mg/ℓ. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: None required

Maximum Holding Time: 7 days

Container Type: Plastic or glass

Sample Volume Required: 50 mℓ

Measurement: The mercuric nitrate method is recommended wherein a dilute mercuric nitrate solution is added to an acidified sample in the presence of mixed diphenylcarbazone-bromophenol blue indicator. The method is suitable for all concentration ranges, but to avoid large titration volumes, the sample aliquot should not contain more than 10 to 20 mg Cl per 50 mℓ. Sulfites interfere and, if their presence is suspected, oxidize by treating 50 mℓ of sample with 0.5 to 1.0 mℓ if H_2O_2. Bromide and iodide are titrated in the same manner as chloride. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: A synthetic unknown sample containing 241 mg/ℓ Cl was analyzed in 10 laboratories with a relative standard deviation of 3.3% and a relative error of 2.9%.

Cost of Analysis: $3 - $4

1029<

CHLORINATED BENZENES

Parameter Group: STORET Units:

General: Chlorinated benzenes (other than dichlorobenzenes) include chlorobenzene, 1, 2, 4-trichlorobenzene, and hexachlorobenzene. They are heavy liquids and settle to the bottom in quiescent water unless emulsified. Their chief use is as aquatic herbicides to control weeds in lakes and ditches. They have pungent odors and therefore are unlikely to cause serious harm to humans through direct ingestion. Mild symptoms of poisoning of sheep and cattle have been reported at concentrations in excess of 2,700 mg/ℓ. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Not determined. Analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 200-1,000 mℓ

Measurement: No standard procedures have been developed. The methodology generally requires extraction, concentration, and gas chromatographic analysis. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Detection limits of 0.1 to 10 µg/ℓ should be achievable. Precision and accuracy data are not available at this time.

Cost of Analysis: $25 - $40

1030<

CHLORINATED ETHANES

Parameter Group: STORET Units:

General: Chlorinated ethanes are volatile halocompounds including: 1, 2-trichloroethane; hexachloroethane; 1, 2-dichloroethane; 1, 1, 1-trichloroethane; hexachloroethane; 1, 1-dichloroethane; 1, 1, 2-trichloroethane; 1, 1, 2, 2-tetrachloroethane; and chloroethane. Widely used in various industries and processes, their characteristics vary from compound to compound. For example, 1, 2-dichloroethane (also called ethylene dichloride, $C_2H_4Cl_2$) is a heavy liquid with a pleasant odor and sweet taste and is highly soluble in water. It is used as an industrial solvent and in the manufacture of tobacco extract. Its oral LD_{50} for rats is 770 mg/kg of body weight. By contrast, 1, 1, 1-trichloroethane (also called methyl chloroform) is insoluble in water. It is used as a solvent for fats, waxes, resins, and alkaloids, and for cleaning metal and plastic molds. Its toxicity towards the marine pinperch is twice that of 1, 1, 2-trichloroethane (i.e., 75-100 mg/ℓ versus 150-175 mg/ℓ). This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Sample history must be known before any chemical or physical preservation steps can be applied to protect against phase separation. Fill the sample bottle completely and seal until analysis is performed. Do not refrigerate.

Maximum Holding Time: Unknown; preferably analyze within 1 hour.

Container Type: Borosilicate glass

Sample Volume Required: In excess of 200 mℓ

Measurement: In the recommended Bellar procedure the sample is stripped with an inert gas; volatiles are captured on an adsorbent trap and desorbed into a modified gas chromatograph equipped with a halogen-specific detector. Methodology should be checked for interferences, e.g., from bromine or iodine. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Sensitivity of the method is approximately 1,000 µg/ℓ. Detection limits of 0.2-3 µg/ℓ may be achieved. Precision and accuracy data are not available at this time.

Cost of Analysis: Around $60

1031<

CHLORINATED NAPHTHALENE

Parameter Group: STORET Units:

General: 2-chloronaphthalene ($C_{10}H_7Cl$) is a solid (at normal temperatures) polynuclear organic compound. It is insoluble in water, but moderately soluble in other media such as alcohol, benzene, and ether. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Not determined. Analyze promptly. Cool to 4°C.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100-1,000 mℓ

Measurement: The general procedure involves extraction and measurement with a gas chromatograph. Various cleanup techniques to remove interferences may be required depending upon other constituents in the sample. A skilled chemist or specialist will be required. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Detection limits in the 1-10 µg/ℓ range should be achievable. Precision and accuracy data are not available at this time.

Cost of Analysis: $40 - $60

CHLORINATED PHENOLS (OTHER)

Parameter Group: STORET Units:

General: Other chlorinated phenols ($C_6H_3Cl_3O$) include the trichlorophenols and chlorinated cresols (C_7H_7ClO). Although their specific properties vary from compound to compound, they are generally only slightly soluble in water but fairly soluble in other media such as alcohol, benzene, and ethers. Their main aesthetic problem stems from their organoleptic properties in water and fish. For example, the threshold odor level in water for 2, 4, 6-trichlorophenol is 3 µg/ℓ. They tend to be persistent in water and are capable of being transported long distances. They are not efficiently removed by conventional water treatment processes and can cause odor problems in distribution systems. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Acidify to a pH of 4 with H_3PO_4. Add 1.0g $CuSO_4 \cdot 5H_2O$/ℓ to inhibit biodegradation of phenols. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Borosilicate glass

Sample Volume Required: 100-1,000 mg/ℓ or more depending upon initial concentration.

Measurement: The recommended method involves direct aqueous injection for the gas-liquid chromatographic determination of concentrates containing more than 1 mg/ℓ phenolic compounds. A flame-ionization detector is used for their individual measurement. Suspended matter may interfere by plugging the microsyringe. Interfering nonphenolic organic compounds may be removed by distillation. Steps should be taken to minimize or eliminate ghosting. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Few precision and accuracy data are available. Precision is very operator dependent. For example, total precision may be 2 to 5 times single operator precision values.

Cost of Analysis: $40 - $60

1033<

CHLORINE DEMAND

Parameter Group: General Inorganic STORET Units: mg/ℓ

General: The chlorine demand of water is caused by inorganic reductants and others and varies with the amount of chlorine applied, contact time, pH, and temperature. It is the difference between the amount of chlorine applied at the amount of free, combined, or total available chlorine remaining at the end of the contact period. The usual purpose of a chlorine demand test is to determine the amount of chlorine that must be applied to produce a specific residual after a selected period of contact, rather than as an indicator of pollution. It should not be confused with chlorine requirement.

Criterion: Not designated

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 200-500 mℓ; 5,000 mℓ may be required to develop a breakpoint curve.

Measurement: A laboratory method is recommended which involves the addition of chlorine to the sample until the "breakpoint" is reached. At the end of the contact period the free and/or combined available residual chlorine is determined by a suitable technique, e.g., the amperometric titration method.

Precision and Accuracy: Precision and accuracy will depend upon the method chosen to measure free and/or combined available residual chlorine.

Cost of Analysis: $50 - $80 with breakpoint curve

CHLORINE DIOXIDE

Parameter Group: STORET Units:

General: Chlorine dioxide is added to water supplies to combat tastes and odors due to phenolic-type wastes, actinomycetes, and algae as well as to oxidize soluble iron and manganese to a more easily removable form. Chlorine dioxide acts as a disinfectant. See also the residual chlorine discussion.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Avoid exposing the sample to sunlight or agitation that aerates the sample excessively.

Maximum Holding Time: No holding. Analyze on site if possible.

Container Type: Plastic or glass

Sample Volume Required: 200 mℓ

Measurement: The amperometric titration method is recommended. It is an extension of the method for residual chlorine.

Precision and Accuracy: Precision and accuracy data are not available.

Cost of Analysis: $30 - $40

1035<

CHLORINE, RESIDUAL

Parameter Group: Miscellaneous STORET Units: mg/ℓ

General: The toxicity of chlorine to aquatic life will depend upon the concentration of total residual chlorine, which is the amount of free chlorine plus chloramines. The persistence of chloramines is dependent on the availability of material with a lower oxidation-reduction potential. Free available chlorine (HOCl and OCl^-) and combined available chlorine (mono- and di-chloramines) appear transiently in surface or ground waters as a result of disinfection of domestic sewage or from industrial processes that use chlorine for bleaching operations or to control organisms that grow in cooling water systems. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criteria: Total residual chlorine:

- 2.0 µg/ℓ for salmonid fish
- 10.0 µg/ℓ for other freshwater and marine organisms

Preservation Method: Analyze as soon as possible Cool to 4°C. Chlorine determinations should be started immediately after sampling, avoiding excessive light and agitation.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 50 mℓ

Measurement: The amperometric titration method is recommended. It is applicable to all types of waters and wastes that do not contain a substantial amount of organic matter. This method cannot be used for samples containing above 5 mg/ℓ total residual chlorine. Samples containing significant amounts of organic matter interfere with the amperometric titration and the iodometric method must be used. The amperometric titration is not subject to interference from color, turbidity, iron, manganese, or nitrite nitrogen. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: A sample containing a concentration of .8 mg/ℓ was analyzed by 23 laboratories using the amperometric method. The relative standard deviation was 42.3% with a relative error of 25.0%.

Cost of Analysis: $30 - $40

1036<

CHLOROALKYL ETHERS

Parameter Group: STORET Units:

General: Chloroalkyl ethers are volatile halocompounds including bis (chloromethyl) ether, bis (2-chloroethyl) ether, and 2-chloroethyl vinyl ether (mixed). This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Sample history must be known before any chemical or physical preservation steps can be applied to protect against phase separation. Fill the sample bottle completely and seal until analysis is performed. Do not refrigerate.

Maximum Holding Time: Unknown; preferably analyze within 1 hour.

Container Type: Borosilicate glass

Sample Volume Required: In excess of 200 mℓ

Measurement: No standard procedure has been established. Methodology may require extraction, concentration, gas chromatography, and mass spectrometry. Detection limits of 60 µg/ℓ or less should be achievable if procedure is optimized for sample composition. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Precision and accuracy data are not available.

Cost of Analysis: $20 - $30 each

1037<
CHLOROFORM

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Chloroform is used as an anesthetic, counterirritant, solvent, cleansing agent, and antiseptic. It is a colorless and volatile liquid with an ethereal odor and sweetish taste. Stickleback will avoid solutions of 100,000 to 200,000 µg/ℓ of chloroform in tap water. At 500,000 µg/ℓ, they become anesthetized. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Sample history must be known before any chemical or physical preservation steps can be applied to protect the sample from phase separation. Fill the sample bottle completely and seal until analysis is performed. Do not refrigerate.

Maximum Holding Time: Unknown; preferably analyze within 1 hour.

Container Type: Borosilicate glass

Sample Volume Required: In excess of 200 mℓ

Measurement: The recommended method for chloroform is a direct aqueous-injection procedure for the determination of gas chromatographable chlorinated hydrocarbons. A 3-10 µℓ aliquot of the sample is injected into the gas chromatograph equipped with a halogen specific detector. Compounds containing bromine or iodine will interfere with the determination. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Sensitivity of the method is approximately 1,000 µg/ℓ. Detection limits of 0.2-3 µg/ℓ may be achieved. Precision and accuracy data are not available at this time.

Cost of Analysis: Around $60.

1038<

2-CHLOROPHENOL

Parameter Group: STORET Units:

General: 2-chlorophenol (C_6H_5ClO) is a liquid only slightly soluble in water but fairly soluble in other media such as alcohol. Its major aesthetic problem stems from its organoleptic properties in water and fish. Threshold odor levels for 2-chlorophenol are around 2 µg/ℓ. It is a persistent substance, capable of being transported long distances in water and is not removed efficiently by conventional water treatment. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Acidify to a pH of 4 with H_3PO_4. Add 1.0g $CuSO_4 \cdot 5H_2O$/ℓ to inhibit biodegradation of phenols. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Borosilicate glass

Sample Volume Required: 100-1,000 mg/ℓ or more depending upon initial concentration.

Measurement: The recommended method involves direct aqueous injection for the gas-liquid chromatographic determination of concentrates containing more than 1 mg/ℓ phenolic compounds. A flame-ionization detector is used for their individual measurement. Suspended matter may interfere by plugging the microsyringe. Interfering nonphenolic organic compounds may be removed by distillation. Steps should be taken to minimize or eliminate ghosting. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Few precision and accuracy data are available. Precision is very operator dependent. For example, total precision may be 2 to 5 times single operator precision values.

Cost of Analysis: $40 - $60

1039<

CHROMIUM

Parameter Group: Metals STORET Units: µg/ℓ as Cr

General: The primary source of chromium is industrial discharges. Chromium compounds are used in cooling water to inhibit corrosion and are employed in the manufacture of paint pigments, in chrome tanning, aluminum anodizing, and other metal cleaning, plating, and electroplating operations. Chromium in industrial wastes occurs predominately as the hexavalent form, but the trivalent form is also present, either as a result of partial wastewater treatment or from its direct use. Industries that use trivalent chromium directly in manufacturing processes include glass, ceramics, photography, and textile dyeing. It is not clear if chromium is an essential element to man. Hexavalent chromium has been considered a toxic metal for years. Trivalent chromium is less toxic, no reports of oral toxicity are known. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criteria:

- 50 µg/ℓ for domestic water supply (health)
- 100 µg/ℓ for freshwater aquatic life

Preservation Method: Acidify all samples at the time of collection to keep the metal in solution and prevent plating out on the container wall; therefore, analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended for the determination of total chromium in water and wastewater samples. The colorimetric method may be used for the determination of hexavalent chromium in potable water. Use a wavelength of 357.9 nm with the AA spectrophotometric method. The absorption of chromium is suppressed by iron and nickel. If the analysis is performed in a lean flame the interference can be lessened but the sensitivity will also be reduced. The interference does not exist in nitrous oxide-acetylene flame. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 100 µg/ℓ; its detection limit is 20 µg/ℓ. The optimum concentration range is 200-10,000 µg/ℓ. At a concentration of 50 µg/ℓ, the relative standard deviation is 26.4%, and the relative error is 2.3%. These decrease with concentration; at 15.0 µg/ℓ they are 60% and 6.8% respectively, while at 7.4 µg/ℓ they are 105% and 38%, respectively.

Cost of Analysis: $10 - $15

1041<

COBALT

Parameter Group: Metals STORET Units: µg/ℓ as Co

General: Cobalt naturally occurs primarily as arsenide and sulfide, generally associated with iron, nickel, copper, and silver minerals. Cobalt is used in alloys for magnets, high hardness steels, cutting tools, heat resistant jet engine parts, etc., and may appear in discharges from these and other industrial sources, including nuclear technology, china and glass, ink, galvanoplating, and as a feed supplement in salt licks. Ingestion of cobalt salts may cause nausea or vomiting due to irritation, but it has a relatively low toxicity to man. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 240.7 nm. For levels of cobalt below 50 mg/ℓ, the extraction procedure is recommended. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 200 µg/ℓ; its detection limit is 30 µg/ℓ. The optimum concentration range is 500-10,000 µg/ℓ. In a single laboratory, using a mixed industrial-domestic waste effluent at concentrations of 200, 1,000 and 5,000 µg Co/ℓ, the relative standard deviations were 6.5%, 1.0%, and 1.0%, respectively. Recoveries at these levels were 98%, 98%, and 97%, respectively.

Cost of Analysis: $10 - $15

1042<

COLOR

Parameter Group: Physical STORET Units: Platinum-Cobalt Units

General: The most common causes of color in natural water are minerals and complex organic compounds originating from the decomposition of naturally-occurring organic matter. Sources of organic material include humic materials from the soil such as tannins, humic acid and humates; decaying plankton; and other decaying aquatic plants. Virtually all industrial discharges and irrigation return flows also contain color to varying extents. The effects of color on public water supplies are aesthetic. The effects of color in water on aquatic life are to reduce light penetration, and thereby generally reduce photosynthesis by phytoplankton and to restrict the zone for aquatic vascular plant growth. Color is undesirable in waters for a number of industrial uses also. Color values are extremely pH dependent. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criteria:

- Waters shall be virtually free from substances producing objectionable color for aesthetic purposes;
- The source of supply should not exceed 75 color units on the platinum-cobalt scale for domestic water supplies;
- Increased color (in combination with turbidity) should not reduce the depth of the compensation point for photosynthetic activity by more than 10 percent from the seasonally established norm for aquatic life.

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 50 mℓ

Measurement: The platinum-cobalt visual comparison method is acceptable for measuring the color of potable water. The method is not applicable to color measurement on waters containing highly colored industrial wastes, in which case the spectrophotometric or tristimulus methods are useful. In the platinum-cobalt method, color is measured by visual comparison of the sample with platinum-cobalt standards. One unit of color is that produced by

1 mg/ℓ platinum in the form of the chloroplatinate ion. Slight amounts of turbidity interfere with the determination; therefore, samples showing visible turibidity should be clarified by centrifugation. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Precision and accuracy data are not available at this time.

Cost of Analysis:
$3 - $5 for visual
$10 - $15 for tristimulus
$30 - $40 for spectrophotometric (10 ordinates)
$70 - $80 for spectrophotometric (30 ordinates)

1044
COPPER

Parameter Group: Metals STORET Units: µg/ℓ as Cu

General: Oxides and sulfates of copper are used for pesticides, algicides, and fungicides. Copper is frequently incorporated into paints and wood preservatives to inhibit growth of algae and invertebrate organisms. Copper salts are used in water supply systems for controlling biological growths and for catalyzing the oxidation of manganese. Primary sources of copper in industrial wastewater are metal process pickling and plating baths; other sources involve mine drainage, pulp and paper mills, fertilizer manufacturing, petroleum refining, and certain rayon processes. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criteria:

- 1.0 mg/ℓ for domestic water supplies (welfare).
- For freshwater and marine aquatic life, 0.1 times a 96-hour LC_{50} as determined through nonaerated bioassay using a sensitive aquatic resident species.

Preservation Method: Copper ion tends to be adsorbed on the surface of the sample container; therefore, analyze as soon as possible. If storage is necessary, use 0.5 mℓ 1 + 1 HCl per 100 mℓ of sample to prevent plating out. Alternatively, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 50 to 200 mℓ

Measurement: The AA spectrophotometric and neocupreine methods are recommended because of their high degree of freedom from interferences. The latter requires either a spectrophotometer for use at 457 nm or a filter photometer equipped with a narrow-band violet filter having maximum transmittance in the 450- to 460-nm range; either must provide a light path of at least 1 cm. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 100 µg/ℓ; its detection limit is 100 µg/ℓ. Precision and accuracy decrease with concentration. At 1,000 µg/ℓ, the relative standard deviation is around 11% and the relative error, 3%. At 300 µg/ℓ, the relative standard deviation has increased to nearly 18%, at 70 µg/ℓ it is over 30%, and approaching 10 µg/ℓ it exceeds 80%. Relative error has increased to nearly 16% at the last concentration.

Cost of Analysis: $5 - $10

1046<

CYANIDE

Parameter Group: General Inorganic

STORET Units: mg/ℓ as CN

General: All of the CN groups in cyanide compounds that can be determined as the cyanide ion, CN^-, whether in simple, e.g., A(CN)x, or complex, AyM(CN)x, form. In the first expression, A may be an alkali or a metal; in the second, A is an alkali and M a heavy metal. In such latter alkali-metallic cyanides, the anion is not the CN group but the radical M(CN)x. Sources of cyanide in waste streams include ore mining and extracting, photographic processing, coke furnaces, synthetic manufacturing, case hardening and pickling of steel, electroplating, and industrial gas scrubbing. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 5.0 µg/ℓ for freshwater and marine aquatic life and wildlife.

Preservation Method: Most cyanides are very reactive and unstable. Analyze as soon as possible. If oxidizing agents are present, reduce with ascorbic acid. Add NaOH to raise sample pH to 12 or above and cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 500 mℓ

Measurement: For total cyanides, both dissociable and nondissociable forms of cyanide are being measured. Cyanides amenable to chlorination represent only the former. Standard methods for determination of total cyanide make use of a reflux-distillation procedure for concentrating and removing cyanides. The liberated hydrogen cyanide is collected in sodium hydroxide, and its concentration determined by using a titration method (above 1 mg/ℓ), a colorimetric method (below 1 mg/ℓ), or an ion selective electrode method (0.05 to 10 mg/ℓ). Although the distillation procedure eliminates or reduces many interferences, sulfides will distill over and adversely affect the colorimetric and titrimetric procedures, fatty acids will distill and form soaps under the alkaline titration procedures obscuring the end point, thiocyanates may interfere when distillation is carried out with the cuprous chloride reagent, and aldehydes will convert cyanide to nitrile under the distillation conditions. Special precautions are required when any of these are present. The colorimetric method requires either a spectrophotometer for use at 578 nm or a filter photometer equipped with a red filter having maximum transmittance

in the 570 to 580 nm range; either must provide a light path of 1 cm. The ion selective electrode method requires a suitable meter, a cyanide-ion selective electrode, and a double junction reference electrode. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The titrimetric method yields a relative standard deviation of 2% for samples containing more than 1 mg/ℓ CN without significant interferences, increasing with decreasing concentration down to the limit of sensitivity, which is around 0.1 mg/ℓ, e.g., at 0.4 mg/ℓ the relative standard deviation is 8%. The colorimetric method is sensitive to about 0.02 mg/ℓ. Within its designated range, its overall precision is given as 0.115X + 0.031, where X is the CN concentration in mg/ℓ. Using mixed domestic and industrial waste samples at concentrations of 0.28 and 0.62 mg/ℓ CN, relative standard deviations of 11% and 15% and recoveries of 85% and 102%, respectively, were observed in a single laboratory. The overall precision of the ion selective electrode method is given as 0.113X + 0.024, where X is the concentration in mg/ℓ CN.

Cost of Analysis: $10 - $30

CAUTION! Exercise care in the manipulation of cyanide samples because of their toxicity. Avoid contact, inhalation, or ingestion.

1018
2, 4-D

Parameter Group: Pesticides STORET Units: µg/ℓ

General: 2, 4-D (2, 4-dichlorophenoxyacetic acid) is the widely used chlorophenoxy herbicide $C_8H_6Cl_2O_3$. This compound is formulated in a variety of salts and esters that may have a marked difference in herbicidal properties, but all are hydrolyzed rapidly to the corresponding acid in the body. 2, 4-D herbicide is used for weed control on land, and as an aquatic herbicide in lakes, streams, and irrigation canals. It is a plant hormone that stimulates excessive growth, causing the plant to destroy itself. 2, 4-D is of low toxicity to mammals, the acute oral LD_{50} for rats being 500,000 µg/kg of body weight, but may give water an unpleasant taste. Fish toxicity levels are in the hundreds of mg/ℓ. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 100 µg/ℓ for domestic water supply (health).

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100-1,000 mℓ, depending upon measurement method used.

Measurement: In the recommended method, chlorinated phenoxy acids and their esters are extracted from the acidified water sample with ethyl ether. The esters are hydrolyzed to acids and extraneous organic material is removed by a solvent wash. The acids are converted to methyl esters which are extracted from the aqueous phase. The extract is cleaned up by passing it through a micro-adsorption column. Detection and measurement are accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography. Interferences may be high and varied and often pose great difficulty in obtaining accurate and precise measurement of chlorinated phenoxy acid herbicides. Organic acids, especially chlorinated acids, cause the most direct interference with the determination. Phenols including chlorophenols will also interfere with this procedure. The method is recommended for use only by an experienced pesticide analyst (or under the close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Sensitivity of the method is 1 µg/ℓ. Detection limits of 0.05 µg/ℓ or so may be achieved. Precision and accuracy data are not available at this time.

Cost of Analysis: $45 - $150, depending upon preparation required.

1050<

DDD

Parameter Group: Pesticides STORET Units: µg/ℓ

General: DDD, a metabolite of DDT, is an organochlorine insecticide. It is the same as TDE and is also known as Rhothane. DDD has much the same properties and is used similarly to DDT. Its insecticidal activity approaches that of DDT, but its mammolian toxicity is only about 20% of that of DDT. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants. A toxic effluent limitation has been prescribed for this parameter by the NPDES permits program.

Criterion: Not established

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for DDD. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 µg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration.

Cost of Analysis: $30 - $150, depending upon preparation required.

1051<

DDE

Parameter Group: Pesticides STORET Units: µg/ℓ

General: DDE, a metabolite of DDT, is an organochlorine insecticide. It is the same as DDX. DDE has much the same properties and is used similarly to DDT. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants. A toxic effluent limitation has been prescribed for this parameter by the NPDES permits program.

Criterion: Not established

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for DDE. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 µg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration.

Cost of Analysis: $30 - $150, depending upon preparation required.

1052<

DDT

Parameter Group: Pesticides STORET Units: µg/ℓ

General: DDT (1, 1, 1-trichloro -2, 2-bis (p-chlorophenyl) ethane) is an organochlorine insecticide. Acute toxicity to mammals generally is low. DDT is a highly persistent chemical which bioaccumulates in aquatic organisms used for human food and also is considered a potential human carcinogen. DDT will accumulate in the food chain. A residue accumulation of up to two million times for fish can occur. Application of DDT in agriculture and forest areas contributes to the presence of this toxic material in surface and ground waters. Practically insoluble in water, dilute acids, and alkalies, it is readily soluble in many organic solvents. The vehicle is very important in determining the toxicity of DDT. It has been found in river waters at concentrations to 20 µg/ℓ. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants. A toxic effluent limitation has been prescribed for this parameter by the NPDES permits program.

Criterion:

- 0.001 µg/ℓ for freshwater and marine aquatic life
- The persistence, bioaccumulation potential, and carcinogenicity of DDT cautions human exposure to a minimum.

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for DDT. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 µg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration. For example, at the 0.040 and 0.200 µg/ℓ concentrations, recoveries were around 101% and 77% and precisions were 40% and 19%, respectively.

Cost of Analysis: $30 - $150, depending upon preparation required.

1054<

DEMETON

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Demeton (also known as Systox) is the organophosphorus insecticide $C_8H_{19}O_3PS_2$. Commercial demeton is a mixture of isomers of varying toxicities. It is insoluble in water but soluble in alcohol. The estimated fatal dose to a 70-kg man is 0.1 gram. The acute oral LD_{50} for stock and wildlife is reported between 2,500 to 40,000 µg/kg of body weight. Toxicity to aquatic life varies widely with age and species. Demeton is unique in that the persistence of its ACHE enzyme inhibiting ability is greater than that of ten other common organophosphates, even though its acute toxicity is apparently less. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 0.1 µg/ℓ for freshwater and marine acquatic life.

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100 mℓ or more

Measurement: The use of co-solvent extraction, column chromatography, and liquid-liquid partition, and detection and measurement accomplished by flame photometric gas chromatography using a phosphorus specific filter is recommended for demeton. Great care must be exercised in the selection and use of methods to minimize interferences, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors but is usually 0.010 µg/ℓ or higher. Sensitivity is typically 1 µg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $30 - $150, depending upon preparation required.

1055<

DIAZINON

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Diazinon is the registered trade name of an organophosphorus insecticide. It is a liquid with a faint ester-like odor and is miscible with a number of hydrocarbon solvents. Diazinon has very high insecticidal and acaricidal properties. The estimated fatal dose for a 70-kg man is 25 grams. The oral LD_{50} to rats ranges from 100,000 to 435,000 µg/kg of body weight. Toxicity data for aquatic life are limited. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100 mℓ or more

Measurement: The use of co-solvent extraction, column chromatography, and liquid-liquid partition, and detection and measurement accomplished by flame photometric gas chromatography using a phosphorus specific filter is recommended for diazinon. Great care must be exercised in the selection and use of methods to minimize interferences, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but is usually 0.010 µg/ℓ or higher. Sensitivity is typically 1 µg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $30 - $150, depending upon preparation required.

1056<
DICHLOROBENZENES

Parameter Group: STORET Units:

General: Dichlorobenzenes ($C_6H_4Cl_2$) include 1, 2-dichlorobenzene, 1, 3-dichlorobenzene, and 1, 4-dichlorobenzene. Metadichlorobenzene is a colorless liquid, insoluble in water, and seldom used commercially. Othodichlorobenzene is also a liquid and insoluble in water and is used as a solvent for waxes, for preserving plants, and for destroying insects such as termites. Paradichlorobenzene is a white crystallic solid with a characteristic odor used chiefly for killing moths, their larvae, and other insects. It is slightly soluble in water, 70 mg/ℓ at 25°C. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Not determined. Analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 200-1,000 mℓ

Measurement: No standard procedures have been developed. The methodology generally requires extraction, concentration, and gas chromatographic analysis. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Detection limits of 0.1 to 10 µg/ℓ should be achievable. Precision and accuracy data are not available at this time.

Cost of Analysis: $25 - $40

1057<

DICHLOROBENZIDINE

Parameter Group: STORET Units:

General: Dichlorobenzidine (3, 3'-dichlorobenzidine) is a polynuclear organic compound. Due to its suspected carcinogenic properties, it must be handled with great care. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 1 week

Container Type: Borosilicate glass

Sample Volume Required: 1,000-4,000 mℓ depending on concentration and instrument used.

Measurement: Dichlorobenzidine is separated and concentrated by multiple extractions and then oxidized by chloramine T. The oxidation product is extracted and measured spectrophotometrically. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The detection limit is approximately 0.2 µg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $20 - $40; because of its carcinogenic properties, special facilities may be required at greatly increased cost.

1058<

DICHLOROETHYLENES

Parameter Group: STORET Units:

General: Dichloroethylenes are volatile halocompounds including 1, 1-dichloroethylene and 1, 2-dichloroethylene. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Sample history must be known before any chemical or physical preservation steps can be applied to protect against phase separation. Fill the sample bottle completely and seal until analysis is performed. Do not refrigerate.

Maximum Holding Time: Unknown; preferably analyze within 1 hour.

Container Type: Borosilicate glass

Sample Volume Required: In excess of 200 mℓ

Measurement: In the recommended Bellar procedure the sample is stripped with an inert gas; volatiles are captured on an adsorbent trap and desorbed into a modified gas chromatograph equipped with a halogen-specific detector. Methodology should be checked for interferences, e.g., from bromine and iodine. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Sensitivity of the method is approximately 1,000 µg/ℓ. Detection limits of 0.2-3 µg/ℓ may be achieved. Precision and accuracy data are not available at this time.

Cost of Analysis: Around $60

1059<

2, 4-DICHLOROPHENOL

Parameter Group: STORET Units:

General: 2, 4-dichlorophenol ($C_6H_4Cl_2O$) is a colorless, crystalline substance only slightly soluble in water but fairly soluble in other media such as alcohol. It is used in the manufacture of the herbicide 2, 4-D as well as for other purposes. It is persistent and, since it is not efficiently removed by conventional water treatment processes, can cause odor problems in distribution systems. Fish flesh tainting concentrations range from 1 to 5 µg/ℓ, levels that do not appear to adversely affect the fish. The threshold odor level in water is as low as 1 µg/ℓ. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Acidify to a pH of 4 with H_3PO_4. Add 1.0g $CuSO_4 \cdot 5H_2O$/ℓ to inhibit biodegradation of phenols. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Borosilicate glass

Sample Volume Required: 100-1,000 mg/ℓ or more depending upon initial concentration.

Measurement: The recommended method involves direct aqueous injection for the gas-liquid chromatographic determination of concentrates containing more than 1 mg/ℓ phenolic compounds. A flame-ionization detector is used for their individual measurement. Suspended matter may interfere by plugging the microsyringe. Interfering nonphenolic organic compounds may be removed by distillation. Steps should be taken to minimize or eliminate ghosting. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Few precision and accuracy data are available. Precision is very operator dependent. For example, total precision may be 2 to 5 times single operator precision values.

Cost of Analysis: $40 - $60

1060<

DICHLOROPROPANE

Parameter Group: STORET Units:

General: 1, 2-dichloropropane (also called propylene chloride, $C_3H_6Cl_2$) is a heavy liquid that is slightly soluble in water. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Sample history must be known before any chemical or physical preservation steps can be applied to protect against phase separation. Fill the sample bottle completely and seal until analysis is performed. Do not refrigerate.

Maximum Holding Time: Unknown; preferably analyze within 1 hour.

Container Type: Borosilicate glass

Sample Volume Required: In excess of 200 mℓ

Measurement: In the recommended Bellar procedure the sample is stripped with an inert gas; volatiles are captured on an adsorbent trap and desorbed into a modified gas chromatograph equipped with a halogen-specific detector. Methodology should be checked for interferences, e.g., from bromine or iodine. Confirmation should be made for dichloropropane. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Sensitivity of the method is approximately 1,000 µg/ℓ. Detection limits of 0.2-3 µg/ℓ may be achieved. Precision and accuracy data are not available at this time.

Cost of Analysis: Around $60

1061<

DICHLOROPROPENE

Parameter Group: STORET Units:

General: 1, 3-dichloropropene ($C_3H_4Cl_2$) is a heavy liquid, insoluble in water, and with a chloroform-like odor. It is used as a soil fumigant for the control of nematodes. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Sample history must be known before any chemical or physical preservation steps can be applied to protect against phase separation. Fill the sample bottle completely and seal until analysis is performed. Do not refrigerate.

Maximum Holding Time: Unknown; preferably analyze within 1 hour.

Container Type: Borosilicate glass

Sample Volume Required: In excess of 200 mℓ

Measurement: In the recommended Bellar procedure the sample is stripped with an inert gas; volatiles are captured on an adsorbent trap and desorbed into a modified gas chromatograph equipped with a halogen-specific detector. Methodology should be checked for interferences, e.g., from bromine or iodine. Confirmation should be made for dichloropropene. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Sensitivity of the method is approximately 1,000 µg/ℓ. Detection limits of 0.2-3 µg/ℓ may be achieved. Precision and accuracy data are not available at this time.

Cost of Analysis: Around $60

1062<
DIELDRIN

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Dieldrin, the common name for an organochlorine insecticide, is a highly persistent chemical which bioaccumulates in aquatic organisms used for human food and is also considered a potential human carcinogen. The USEPA has suspended the production and use of dieldrin. This should result in a gradual decrease in concentration in the environment. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants. A toxic effluent limitation has been prescribed for this parameter by the NPDES permits program.

Criteria:

- .003 µg/ℓ for freshwater and marine aquatic life
- The persistence, bioaccumulation potential, and carcinogencity of dieldrin cautions human exposure to a minimum.

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for dieldrin. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 µg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration. For example, at the 0.02 and 0.125 µg/ℓ concentration, recoveries were around 108% and 85% and precisions were 91% and 24%, respectively.

Cost of Analysis: $30 - $150 depending upon preparation required.

2, 4-DIMETHYLPHENOL

Parameter Group: STORET Units:

General: 2, 4-dimethylphenol (2, 4-dimethyl-1-hydroxybenzene) is only slightly soluble in water but highly soluble in other media such as alcohol. It has a higher odor threshold concentration than many other phenolic compounds, up to 75 µg/ℓ. It is a persistent substance, capable of being transported long distances in water and is not removed efficiently by conventional water treatment processes. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Acidify to a pH of 4 with H_3PO_4. Add 1.0g $CuSO_4 \cdot 5H_2O$/ℓ to inhibit biodegradation of phenols.

Maximum Holding Time: 24 hours

Container Type: Borosilicate glass

Sample Volume Required: 100-1,000 mg/ℓ or more depending upon initial concentration.

Measurement: The recommended method involves direct aqueous injection for the gas-liquid chromatographic determination of concentrates containing more than 1 mg/ℓ phenolic compounds. A flame-ionization detector is used for their individual measurement. Suspended matter may interfere by plugging the microsyringe. Interfering nonphenolic organic compounds may be removed by distillation. Steps should be taken to minimize or eliminate ghosting. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Few precision and accuracy data are available. Precision is very operator dependent. For example, total precision may be 2 to 5 times single operator precision values.

Cost of Analysis: $40 - $60

DISSOLVED OXYGEN

Parameter Group: Dissolved Oxygen STORET Units: mg/ℓ

General: Dissolved oxygen (DO) levels in water, an important gage of its overall quality, depend upon its physical, chemical, and biological activities. Although excessive DO may be detrimental to certain uses (e.g., it increases metallic corrosion), the main concern is with DO deficiencies. Insufficient DO in the water column may be detrimental to aquatic fauna, causes anaerobic decomposition of any organic materials present, and generally degrades the aesthetic quality of the water body. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criteria:

- Aesthetics: Water should contain sufficient dissolved oxygen to maintain aerobic conditions in the water column and, except as affected by natural phenomena, at the sediment-water interface.

- Freshwater aquatic life: A minimum concentration of dissolved oxygen to maintain good fish populations is 5.0 mg/ℓ. The criterion for salmonid spawning beds is a minimum of 5.0 mg/ℓ in the interstitial water of the gravel.

Preservation Method: Electrode: determine on site; Winkler: fix on site.

Maximum Holding Time: No holding

Container Type: Glass only

Sample Volume Required: 300 mℓ

Measurement: The electrode method is recommended for a variety of reasons, including freedom from interferences and, when used in situ, from sampling effects that are otherwise difficult to account for. Modified Winkler methods may be used, but great care in sampling and accounting for interferences must be exercised. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: With most commercially available membrane electrode systems an accuracy of ±0.1 mg/ℓ and a precision of ±0.05 mg/ℓ should be obtainable. No meaningful precision and accuracy data are available for the modified Winkler method.

Cost of Analysis: $3 - $6

1065<
DISYSTON

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Disyston, an organophosphorus insecticide, is a clear, oily liquid that is slightly soluble in water and quite soluble in most organic solvents. Its acute oral LD_{50} to rats has been reported from 2,600 to 12,500 µg/kg of body weight. Toxicity data for aquatic life are sparse but indicate a wide variability with age and species. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100 mℓ or more

Measurement: The use of co-solvent extraction, column chromatography, and liquid-liquid partition, and detection and measurement accomplished by flame photometric gas chromatography using a phosphorus specific filter is recommended for disyston. Great care must be exercised in the selection and use of methods to minimize interferences, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but is usually 0.010 µg/ℓ or higher. Sensitivity is typically 1 µg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $30 - $150, depending upon preparation required.

1066<
DIURON

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Diuron is the urea pesticide $C_9H_{10}Cl_2N_2O$. It is a crystalline compound only slightly soluble in water and oils. Its acute oral LD_{50} to rats is 3,400 µg/ℓ of body weight. Its toxicity to fish varies widely with age and species, but lethal doses are measured in mg/ℓ concentrations. Apparently, aeration slightly reduces the toxicity of diuron to aquatic life. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 1,000 mℓ

Measurement: The recommended method involves an extraction process with methylene chloride and the concentrated extract is cleaned up with a Florisil column. A thin-layer chromatography process is then used. The layer is sprayed with 1-naphthol and the products appear as colored spots. The measurement is achieved visually. Direct interferences may be encountered from aromatic amines that may be present in the sample. Indirect interferences may be encountered from naturally colored materials whose presence masks the chromogenic reaction. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The determination can be made with a sensitivity of 1 µg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $30 - $60

1067<
ENDOSULFAN

Parameter Group: Pesticides STORET Units: µg/ℓ

General: The acute toxicity of endosulfan, an organochlorine insecticide, to different fish species varies widely. No data are available on the levels to which endosulfan could be expected to accumulate in tissues of aquatic organisms at various water concentrations. Residues in fish are not anticipated to pose a hazard to fish-eating predators because of endosulfan's low oral toxicity to birds and mammals. Application of endosulfan in agriculture and forest areas contributes to the presence of this toxic material in surface and ground waters. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criteria:

- 0.003 µg/ℓ for freshwater aquatic life
- 0.001 µg/ℓ for marine aquatic life

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for endosulfan. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 µg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration.

Cost of Analysis: $30 - $150, depending upon preparation required.

1068<
ENDRIN

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Application of endrin, an organochlorine insecticide, in agriculture and forest areas contributes to the presence of this toxic material in surface and ground waters. It is possible that some fish would accumulate endrin to 30,000 times water concentration. Although it has strong residual toxicity as does its closely related compound dieldrin, endrin has been found to be eliminated quickly after termination of exposure and to disappear relatively quickly. Thus, it does not appear to cause an accumulation problem. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants. A toxic effluent limitation has been prescribed for this parameter by the NPDES permits program.

Criteria:

- 0.2 µg/ℓ for domestic water supply (health)
- 0.004 µg/ℓ for freshwater and marine aquatic life

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for endrin. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 µg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration.

Cost of Analysis: $30 - $150, depending upon preparation required.

1069<

ETHYLBENZENE

Parameter Group: STORET Units:

General: Ethylbenzene (C_8H_{10}) is a volatile, flammable liquid with an ethereal odor. It is insoluble in water at normal temperatures. It is used commercially as a solvent and in the synthesis of other organic compounds. Its toxicity to fish varies with water temperature, age, and species. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Not determined. Analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 200-1,000 mℓ

Measurement: Hexadecone extraction followed by gas chromatographic and mass spectrometric analysis is often used. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Detection limits should be around 2-10 µg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $15 - $30

1070<

FECAL COLIFORM

Parameter Group: Bacteriologic STORET Units: MPN

General: Pollution of aquatic systems by the excreta of warm-blooded animals creates public health problems for man and animals and potential disease problems for aquatic life. It is known that enteric microbial pathogens may inhabit the gut of most warmblooded animals and are shed in feces. The presence of bacterial, viral, protozoan, and possibly fungal species is indicated by the presence of the fecal coliform group of bacteria. The number of fecal coliforms present is indicative of the degree of health risk associated with using the water for drinking, swimming, or shellfish harvesting. The fecal coliform bacteria, which comprise a portion of the total coliform group, are able to grow at 44.5°C and ferment lactose, producing acid and gas. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criteria:

Bathing Waters

Based on a minimum of not less than five samples taken over a 30-day period, the fecal coliform bacterial level should not exceed a log mean of 200 per 100 mℓ, nor should more than 10 percent of the total samples taken during any 30 day period exceed 400 per 100 mℓ.

Shellfish Harvesting Waters

Not to exceed a median fecal coliform bacterial concentration of 14 MPN per 100 mℓ with not more than 10 percent of samples exceeding 43 MPN per 100 mℓ for the taking of shellfish.

Preservation Method: Cool to 4°C. Add a dechlorinating agent (e.g., sodium thiosulfate) if residual chlorine is present. Samples high in heavy metals should have a chelating agent (e.g., EDTA) added to reduce metal toxicity.

Maximum Holding Time: 6 hours (30 hours absolute maximum for potable water samples).

Container Type: Plastic or glass

Sample Volume Required: 100 mℓ

Measurement: The multiple tube fermentation technique may be used if a determination of the total coliform group is also being made. Otherwise, the simpler membrane filter technique is

recommended. Results of the former are expressed statistically as the Most Probable Number (MPN), while the latter are expressed as number of colonies per 100 mℓ. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The accuracy of the membrane filter technique for differentiating between coliforms from warm-blooded animals and coliforms from other sources is approximately 93%.

Cost of Analysis: $10 - $12 MFT
$15 - $20 MPN

1072<

FECAL STREPTOCOCCI

Parameter Group: Bacteriologic STORET Units: Unspecified

General: The normal habitat of the fecal streptococcus group of bacteria is the intestines of man and other warm-blooded animals and, thus, these organisms are indicators of fecal pollution. Because of their survival characteristics, it is not recommended that fecal streptococci be used as the sole fecal indicator. Since certain fecal streptococci are host-specific, they may provide valuable additional information about the source of pollution; e.g., a predominance of S. bovis and S. equinus would indicate excrement from nonhuman, warm-blooded animals as, for example, from feedlot and farmland runoff, dairy wastes, and meat processing plants. S. faecalis var liquefaciens is not restricted to the intestines of warm-blooded animals, being also associated with vegetation, insects, and certain types of soils. Biochemical characterization is required to eliminate the possibility of a preponderance of this latter type, thus avoiding misinterpretation of results. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Cool to 4°C. Add a dechlorinating agent (e.g., sodium thiosulfate) if residual chlorine is present. Samples high in heavy metals should have a chelating agent (e.g., EDTA) added to reduce metal toxicity.

Maximum Holding Time: 6 hours (30 hours absolute maximum for potable water samples).

Container Type: Plastic or glass

Sample Volume Required: 100 mℓ

Measurement: The multiple tube fermentation technique and the simpler membrane filter technique are both recommended, especially for nondrinking water tests. Results of the former are expressed statistically as the Most Probable Number (MPN), while the latter are expressed as number of colonies per 100 mℓ. The fecal streptococcal plate count method may also be used. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Not applicable

Cost of Analysis: $10 - $12 MFT
$15 - $20 MPN

1073<
FLUORIDE

Parameter Group: General
Inorganic

STORET Units: mg/ℓ as F

General: The most reactive nonmetal, flourine is never found free in nature, but it is a constitute of a number of minerals. Fluorides in high concentrations are not common in natural surface waters. They are used as insecticides, as disinfectants, as a flux in steelmaking, for preserving wood and mucilages, for the manufacture of glass and enamels, in chemical industries, toothpaste manufacture, for water treatment, and a host of minor applications. They are not normally found in industrial wastes (other than traces) except as a result of spillage. In sufficient quantities (over 200 mg), fluorides can be toxic to humans. Up to 5 mg/ℓ the only bad effect seems to be tooth discoloration. Under 100 mg/ℓ produces little adverse effects on plants. Toxic effects on aquatic life are observed starting at concentrations above 2 mg/ℓ. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 7 days

Container Type: Plastic or glass

Sample Volume Required: 300 mℓ

Measurement: The SPADNS method with Bellack distillation is recommended. A spectrophotometer for use at 570 nm or a filter photometer equipped with a greenish yellow filter having maximum transmittance at 550-580 nm is required; either must have a light path of at least 1 cm. The method covers the range from 0.1 to about 2.5 mg/ℓ F. Following distillation to remove interferences, the sample is treated with the SPADNS reagent. The loss of color resulting from the reaction of fluoride with the zirconyl-SPADNS dye is a function of the fluoride concentration. The SPADNS reagent is more tolerant of interfering materials than other accepted fluoride reagents. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: On a sample containing 0.83 mg/ℓ F with no interferences, the results of 53 analysts using the SPADNS method had a relative standard deviation of 8% and a relative error of 1.2%. After direct distillation, the relative standard deviation was 11.0% and the relative error 2.4%. On a sample containing 0.57 mg/ℓ F (with 200 mg/ℓ SO_4 and 10 mg/ℓ Al as

interferences) results from the 53 analysts had relative standard deviations and errors of 16.2% and 7.0% without distillation and 17.2 and 5.3 with distillation.

Cost of Analysis: $3 - $5 without distillation
$15 - $20 with distillation

GUTHION

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Guthion is the organophosphorus insecticide $C_{10}H_{12}N_3O_3PS_2$. It is a brown waxy solid that is insoluble in water but soluble in most organic solvents. The half-life of guthion spray and dust on cotton leaves has been reported as 2-4 days and 1-2 days for pondwater. An investigation of the persistence of guthion in fish revealed that 50% of the chemical was lost in less than one week. The estimated fatal dose for a 70-kg man is 0.2 grams. The acute oral LD_{50} to rats ranges from 11,000 to 80,000 µg/kg of body weight. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 0.01 µg/ℓ for freshwater and marine aquatic life.

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100 mℓ or more

Measurement: The use of co-solvent extraction, column chromatography, and liquid-liquid partition, and detection and measurement accomplished by flame photometric gas chromatography using a phosphorus specific filter is recommended for guthion. Great care must be exercised in the selection and use of methods to minimize interferences, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but is usually 0.010 µg/ℓ or higher. Sensitivity is typically 1 µg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $30 - $150, depending upon preparation required.

1076<
HALOETHERS

Parameter Group: STORET Units:

General: Haloethers as used here comprise 4-chlorophenyl phenyl ether; 4-bromophenyl phenyl ether, bis (2-chloroisopropyl) ether; and bis (2-chloroethoxy) methane. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Not determined. Analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 200-1,000 mℓ

Measurement: No standard procedures have been developed. The methodology generally requires extraction, concentration, and gas chromatographic analysis. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Detection limits of 1 to 10 µg/ℓ should be achievable. Precision and accuracy data are not available at this time.

Cost of Analysis: $40 - $60

HALOMETHANES

Parameter Group: STORET Units:

General: The halomethanes include dichloromethane (methylene chloride), chloromethane (methyl chloride), bromomethane (methyl bromide), tribromomethane (bromoform), dichlorobromomethane, trichlorofluoromethane (Freon 11), dichlorodifluoromethane (Freon 12), and chlorodibromomethane. These volatile halocompounds are mostly gaseous at surface water temperatures and atmospheric pressure. They range from soluble to insoluble in water; e.g., methyl chloride is soluble to about 4,000 mg/ℓ at 20°C. Chief uses are as refrigerants, aerosol propellents, and certain industrial operations. Taste of water containing halomethanes in appreciable concentrations is sharp, sickening, and sweetish when first taken into the mouth, followed by a burning sensation. It is unlikely that humans would voluntarily drink such water. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Sample history must be known before any chemical or physical preservation steps can be applied to protect against phase separation. Fill the sample bottle completely and seal until analysis is performed. Do not refrigerate.

Maximum Holding Time: Unknown; preferably analyze within 1 hour.

Container Type: Borosilicate glass

Sample Volume Required: In excess of 200 mℓ

Measurement: In the recommended Bellar procedure the sample is stripped with an inert gas; volatiles are captured on an adsorbent trap and desorbed into a modified gas chromatograph equipped with a halogen specific detector. Methodology should be checked for interferences, e.g., from bromine or iodine. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Sensitivity of the method is approximately 1,000 µg/ℓ. Detection limits of 0.2-3 µg/ℓ may be achieved. Precision and accuracy data are not available at this time.

Cost of Analysis: Around $60

1078<

HARDNESS, TOTAL

Parameter Group: General Inorganic

STORET Units: mg/ℓ as $CaCO_3$

General: Water hardness is caused by the polyvalent metallic ions dissolved in water. Principally, these are calcium and magnesium. Other metals such as iron, strontium, and manganese contribute to the extent that appreciable concentrations are present. Natural sources of hardness are soil and geological formations (e.g., limestone) with which the water may have come in contact. Industrial sources include the inorganic chemical industry and discharges from operating and abandoned mines. Irrigation return flows also increase hardness. The detrimental effects of hardness include excessive soap consumption, the formation of scums and curds in laundries and textile mills, the toughening of vegetables cooked in hard water, and the formation of scabs in boilers, hot water heaters, pipes, and utensils. Hence, they are principally economic in nature. The hardness of "good" water should not exceed 250 mg/ℓ. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 7 days

Container Type: Plastic or glass

Sample Volume Required: 100 mℓ

Measurement: The EDTA method, recommended when a complete mineral analysis is not performed, is applicable to drinking, surface, and saline waters, domestic and industrial wastes. Calcium and magnesium ions in the sample are sequestered upon the addition of disodium ethylenediamine tetraacetate (Na_2EDTA). The end point of the reaction is detected by means of Calmagite Indicator, which has a red color in the presence of calcium and magnesium and a blue color when the cations are sequestered. Excessive amounts of heavy metals can interfere. This is usually overcome by complexing the metals with cyanide. Routine addition of sodium cyanide solution to prevent potential metallic interference is recommended. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: A synthetic unknown containing 610 mg/ℓ total hardness as $CaCO_3$ was analyzed in 56 laboratories with a relative standard deviation of 2.9% and a relative error of 0.8%.

Cost of Analysis: $5 - $15

1079<

HEPTACHLOR

Parameter Group: Pesticides STORET Units: µg/ℓ

General: The acute toxicity of heptachlor, a refined ingredient of the well-known organochlorine insecticide chlordane, is generally low to mammals; however, aquatic organisms exhibit sensitivity to this pesticide at microgram-per-liter levels. Heptachlor will accumulate in the food chain. Heptachlor is a highly persistent chemical which bioaccumulates in aquatic organisms used for human food and also is considered a potential human carcinogen. In July 1975, the USEPA suspended the production and use of heptachlor. This should result in a gradual decrease in concentrations in the environment. Any addition of heptachlor to water should be considered potentially hazardous to humans. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion:

- 001 µg/ℓ for freshwater and marine aquatic life
- The persistence, bioaccumulation potential, and carcinogenicity of heptachlor cautions human exposure to a minimum.

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for heptachlor. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

1080<

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 µg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration.

Cost of Analysis: $30 - $150, depending upon preparation required.

1081<

IODIDE

Parameter Group: General Inorganic

STORET Units: mg/ℓ as I

General: Only trace concentrations of iodides are found in natural fresh water; seawater is somewhat higher. Higher concentrations may also be found in natural brines, waters treated with iodine as the disinfectant, and a limited number of industrial wastes. It is used sparingly in industry, e.g., for medicines, germicides, analytical chemistry, and as a table salt additive. All waterborne pathogens are destroyed by 8 mg/ℓ of iodine; no adverse effects were reported when water containing over twice this concentration was consumed in the tropics. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 100 mℓ

Measurement: The titrimetric method is recommended. After pretreatment to remove interferences, the sample is analyzed for iodide by converting the iodide to iodate with bromine water and titrating with phenylarsine oxide (PAU) or sodium thiosulfate. Iron, manganese and organic matter can interfere; however, the calcium oxide pretreatment removes or reduces these to insignificant concentrations. Color interferes with the observation of indicator and bromine-water color changes. This interference can be eliminated by the use of a pH meter instead of a pH indicator and the use of standardized amounts of bromine water and sodium formate solution instead of observing the light yellow color changes. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: In a single laboratory, using a mixed domestic and industrial waste effluent, at concentrations of 1.6, 4.1, 6.6, 11.6, and 21.6 mg/ℓ of iodide, the relative standard deviations were 14.4%, 4.1%, 1.4%, .5%, and 2.3%, respectively. At concentrations of 4.1, 6.6, 11.6 and 21.6 mg/ℓ of iodide, recoveries were 80%, 97%, 97%, and 92%, respectively.

Cost of Analysis: $15 - $20

1082<
IRON

Parameter Group: Metals STORET Units: µg/ℓ as Fe

General: Iron is an essential trace element required by both plants and animals. The ferrous, or bivalent (Fe^{++}), and the ferric, or trivalent (Fe^{+++}) irons, are the primary forms of concern in the aquatic environment. The ferrous (Fe^{++}) form can persist in waters void of dissolved oxygen and originates from groundwaters or mines when these are pumped or drained. The ferric (Fe^{++}) form is insoluble. Potential sources of dissolved iron species include discharges from mining operations, ore milling, chemical industries (organic, inorganic, petrochemical), dye industries, metal processing industries, textile mills, food canneries, tanneries, titanium dioxide production, petroleum refining, and fertilizers. Limitations in drinking water arise primarily from taste consideration. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criteria:

- 0.3 mg/ℓ for domestic water supplies (welfare)
- 1.0 mg/ℓ for freshwater aguatic life

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2. For precise determinations of total iron, use a separate container for sample collection and treat with acid immediately to place the iron in solution and prevent adsorption or desposition on the container walls.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 248.3 nm. The orthophenanthroline method may be used for natural and treated waters. It requires either a spectrophotometer for use at 510 nm or a filter photometer equipped with a green filter having maximum transmittance near 510 nm; either must have a light path of at least 1 cm. In the presence of excessive amounts of organic constituents, the sample should first be digested to ensure complete dissolution of the iron. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 120 µg/ℓ; its detection limit is 20 µg/ℓ. The optimum concentration range is 300-10,000 µg/ℓ. At a concentration of 300 µg/ℓ, the relative standard deviation is 16.5%, and the relative error is 0.6%. For the colorimetric method at 300 µg/ℓ Fe, the values were 25.5% and 13.3%, respectively, from a 44-laboratory test. Serious divergences have been found in reports of different laboratories because of variations in methods of collecting and treating samples.

Cost of Analysis: $3 - $15

1084<

LEAD

Parameter Group: Metals STORET Units: µg/ℓ as Pb

General: Natural lead concentrations in surface waters may range up to 40 µg/ℓ. Lead and its compounds may also enter water at any stage during mining, smelting, and processing. Lead is used in the manufacture of storage batteries, television tubes, printing, pigments, fuels, photographic materials, pesticides, and explosives. The dissolution of lead plumbing is another source. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criteria:

- 50 µg/ℓ for domestic water supply (health)
- 0.01 times the 96-hour LC_{50} value, using the receiving or comparable water as the diluent and soluble lead measurements (nonfilterable lead using a 0.45 micron filter), for sensitive freshwater resident species.

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time. 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 283.3 nm. The analysis of this metal is exceptionally sensitive to turbulence and absorption bands in the flame. Therefore, care should be taken to position the light beam in the most stable, center portion of the flame. The dithizone colorimetric method may also be used. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 500 µg/ℓ; its detection limit is 50 µg/ℓ. The optimum concentration range is 1,000-20,000 µg/ℓ. At a concentration of 50 µg/ℓ, the relative standard deviation is 23.5%, and the relative error is 19.0%. At 25 µg/ℓ, the relative error was 25.7% in a 60-laboratory test.

Cost of Analysis: $10 - $15

1085<

LINDANE

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Lindane, the common name of the gamma isomer of benzene hexachloride (BHC), is an organochlorine insecticide. Application of lindane in agriculture and forest areas contributes to the presence of this toxic material in surface and ground waters. The highest level of lindane found to have minimal or no long-term effects in the most sensitive mammal tested, the dog, is 15.0 mg/kg in the diet or 0.3 mg/kg of body weight/day. An increased resistance to lindane toxicity among fish and invertebrates experiencing previous exposure to the chemical has been observed. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criteria:

- 4.0 µg/ℓ for domestic water supply (health)
- 0.01 µg/ℓ for freshwater aquatic life
- 0.004 µg/ℓ for marine aquatic life

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for lindane. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 µg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration. For

example, at the 0.010 and 0.100 µg/ℓ concentrations, recoveries were around 97% and 73% and precisions were 53% and 26%, respectively.

Cost of Analysis: $30 - $150, depending upon preparation required.

1087<
LITHIUM

Parameter Group: Metals STORET Units: µg/ℓ as Li

General: Lithium is present in fresh waters in concentrations below 10,000 µg/ℓ; brines and thermal waters may be higher. Lithium and its salts are used in dehumidifying units, as a deoxidizer and degasser for nonferrous castings, to form a protective atmosphere in furnaces, in medicinal waters, in metallurgical processes, in the manufacture of some types of glass and storage batteries, and as the hydride for many controlled organic reductions. In addition to these sources, lithium hypochlorite is used as a source of chlorine in some swimming pools. Lithium may have a toxic effect on plants and some forms of aquatic life, but little data exist documenting toxicity to man.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Pyrex bottle

Sample Volume Required: 100-200 mℓ

Measurement: The flame photometric method is often used, using a wavelength of 671 nm. Interferences in the photometric determination include barium, strontium, and calcium. These can be removed by the addition of a sodium sulfate-sodium carbonate solution. Digestion will be necessary if considerable organic matter is present.

Precision and Accuracy: The minimum detectable lithium concentration is approximately 100 µg/ℓ. In a lithium range of 700 to 1,200 µg/ℓ, an accuracy of ±0.1 to 200 µg/ℓ can be obtained in the determination of the lithium concentration.

Cost of Analysis: $12 - $18

1088<
MAGNESIUM

Parameter Group: Metals STORET Units: mg/ℓ as Mg

General: Magnesium salts are important contributors of hardness to water. Sources of magnesium include mining and ore processing, oxide production, metallurgy, refractories, iron and steel production, and its use in flash and incendiary products, signal flares, as a deoxidizer in the casting of metals, as a reagent in organic chemistry, and a host of other applications. Magnesium is an essential element to humans, the daily requirement being about 700 mg. Taste considerations, rather than toxicity, are paramount for magnesium in drinking water. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 285.2 nm. The interference caused by aluminum at concentrations greater than 2 mg/ℓ is masked by the addition of lanthanum. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 0.007 mg/ℓ; its detection limit is 0.0005 mg/ℓ. The optimum concentration range is 0.02-2 mg/ℓ. At a concentration of .2 mg/ℓ, the relative standard deviation is 10.5%, and the relative error is 6.3%. In a single laboratory, using a distilled water sample at concentrations of 2.1 and 8.2 mg/ℓ, the relative standard deviations were 4.7% and 2.4%, respectively. Recoveries at both of these levels were 100%.

Cost of Analysis: $10

1089<

MALATHION

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Malathion, the organophosphorus pesticide $C_{10}H_{19}O_6PS_2$, enters the aquatic environment primarily as a result of its application as an insecticide. Because it degrades quite rapidly in most waters, depending on pH, its occurrence is sporadic rather than continuous. It is soluble in water to 145,000 µg/ℓ. The freshwater fish most sensitive to malathion appear to be the salmonids and centrarchids. Many aquatic invertebrates appear to be more sensitive than fish to malathion. It appears to be about 100 times less toxic to warm-blooded animals than parathion, but only 2 to 4 times less toxic to insects. The estimated fatal dose for a 70-kg man is 60 grams. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 0.1 µg/ℓ for freshwater and marine aquatic life.

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100 mℓ or more

Measurement: The use of co-solvent extraction, column chromatography and liquid-liquid partition, and detection and measurement accomplished by flame photometric gas chromatography using a phosphorus specific filter is recommended for malathion. Great care must be exercised in the selection and use of methods to minimize interferences, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but is usually 0.010 µg/ℓ or higher. Sensitivity is typically 1 µg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $30 - $150, depending upon preparation required.

1090<
MANGANESE

Parameter Group: Metals STORET Units: µg/ℓ as Mn

General: Manganese and its salts are used in manufacturing steel alloys, dry cell batteries, glass and ceramics, paint and varnish, ink and dye, and matches and fireworks. Manganese is normally ingested as a trace nutrient in food. Very large doses of ingested manganese can cause some diseases and liver damage. Inadequate quantities of manganese in domestic animal food results in reduced reproductive capabilities and deformed or poorly maturing young. Manganese imparts objectionable and stubborn stains to laundry and plumbing fixtures. Low limits on domestic water supplies stem from these, rather than toxicological, considerations. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criteria:

- 50 µg/ℓ for domestic water supplies (welfare)
- 100 µg/ℓ for protection of consumers of marine mollusks

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 279.5 nm. For levels of manganese below 25 µg/ℓ, the extraction procedure is recommended. Analytical sensitivity is dependent on lamp current. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 50 µg/ℓ; its detection limit is 10 µg/ℓ. The optimum concentration range is 100-10,000 µg/ℓ. At a concentration of 50 µg/ℓ, the relative standard deviation is 13.5%, and the relative error is 6.0%. These increase at decreasing concentrations. In a 55-laboratory test, at concentrations of 17 and 11 µg/ℓ the relative standard deviations were 118% and 245%, respectively, and the relative errors were 22% and 93%, respectively.

Cost of Analysis: $10

1091<
MERCURY

Parameter Group: Metals STORET Units: µg/ℓ as Hg

General: Mercury is widely distributed in the environment, and biologically is a nonessential or nonbeneficial element. Discharged mercury does not remain localized. Mercury can enter the environment by seeping up through layers of earth to the surface, outgassing of mercury from rock and soil, and transport by natural cycles. Most industrial mercury is eventually lost as waste into streams or the atmosphere. Uses of mercury include the electrical industry, chlor-alkali industry, industrial control equipment, paints, agriculture, dental preparations, pulp and paper industry, catalysts in chemical manufacturing processes, and general laboratory uses. The toxicity of mercury is attributed to its high affinity for sulfur-containing compounds. Toxic effects vary with the form of mercury and its mode of entry into the organism. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criteria:

- 2.0 µg/ℓ for domestic water supply (health)
- 0.05 µg/ℓ for freshwater aquatic life and wildlife
- 0.10 µg/ℓ for marine aquatic life

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 38 days (glass), 13 days (hard plastic)

Container Type: Glass or hard plastic

Sample Volume Required: 100 mℓ

Measurement: The flameless AA spectrophotometric method is recommended. It is a physical method based on the absorption of radiation at 253.7 nm by mercury vapor. The mercury is reduced to the elemental state and aerated from solution in a closed system. The mercury vapor passes through a cell positioned in the light path of an atomic absorption spectrophotometer. Absorbance is measured as a function of mercury concentrations. Possible interference from sulfide is eliminated by the addition of potassium permanganate. Copper has also been reported to interfere. Interference from certain volatile organic materials which will absorb at this wavelength is also possible. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: At a concentration of 0.4 µg/ℓ, the relative standard deviation is 21.2%, and the relative error is 2.4%. In a single laboratory, using an Ohio River composite sample with a background mercury concentration of 0.35 µg/ℓ, spiked with concentrations of 1, 3, and 4 µg/ℓ, the standard deviations were ±0.14, ±0.10, and ±0.08, respectively. Standard deviation at the 0.35 level was ±0.16. Percent recoveries at the three levels were 89%, 87%, and 87%, respectively.

Cost of Analysis: $15 - $25

1093<

METHANE

Parameter Group: STORET Units:

General: Methane is a gaseous saturated (paraffin) hydrocarbon. It is colorless, odorless, tasteless, and flammable. Methane sources include the anaerobic decomposition of organic matter (e.g., some marshes, mines, treatment plants, etc.) and natural gas and petroleum plants. Concern about methane arises from its explosion hazard rather than its negligible toxicity. For example, an explosive limit of methane in air could be reached in a poorly ventilated space sprayed with hot (68°C) water having a methane concentration of only 0.7 mg/ℓ.

Criterion: Not established

Preservation Method: Analyze as soon as possible. When collecting the sample, ensure that the sample is under sufficient pressure to ensure that no gas escapes from the water.

Maximum Holding Time: Unknown, but short

Container Type: Glass

Sample Volume Required: 3,000 mℓ

Measurement: The combustible-gas indicator method is often used. The procedure is based on the catalytic oxidation of a combustible gas or a heated platinum filament that is made a part of a wheatstone bridge. Small amounts of ethane, hydrogen gas, and hydrogen sulfide may interfere. For greater accuracy, a gas chromatograph should be used.

Precision and Accuracy: The sensitivity of the method is approximately 0.2 mg/ℓ. The accuracy of the determination is limited by the accuracy of the instrument employed; errors of around 10% may be expected.

Cost of Analysis: $15 - $20

1094<

METHOXYCHLOR

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Application of methoxychlor, an organochlorine insecticide, in agriculture and forest areas contributes to the presence of this material in surface and ground waters. It is slightly soluble in water but very soluble in alcohol. Sodium and dimethylamine salts are freely soluble in water. The concentration of methoxychlor has been found to be degraded in a few weeks or less in natural waters. The highest level of methoxychlor found to have minimal or no long-term effects in man is 2.0 mg/kg of body weight/day. Few data are available on acute and chronic effects of methoxychlor on freshwater fish. Methoxychlor appears to be considerably less bioaccumulative in aquatic organisms than some of the other organochlorine pesticides. Methoxychlor has a very low accumulation rate in birds and mammals. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criteria:

- 100 µg/ℓ for domestic water supply (health)
- 0.03 µg/ℓ for freshwater and marine aquatic life

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for methoxychlor. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 µg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration.

Cost of Analysis: $30 - $150, depending upon preparation required.

1095<

METHYL PARATHION

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Methyl parathion is an organophosphorus insecticide similar in action to parathion, Phosdrin, and TEPP. Its toxicity is also similar. The half-life of methyl parathion on cotton leaves is less than one hour. The estimated fatal dose for a 70-kg man is 0.15 gram. The acute oral LD_{50} for rats ranges from 9,000 to 25,000 µg/kg of body weight. Toxicity data for aquatic life are sparse but appear to range widely with age and species. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100 mℓ or more

Measurement: The use of co-solvent extraction, column chromatography and liquid-liquid partition, and detection and measurement accomplished by flame photometric gas chromatography using a phosphorus specific filter is recommended for methyl parathion. Great care must be exercised in the selection and use of methods to minimize interferences, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but is usually 0.010 µg/ℓ or higher. Sensitivity is typically 1 µg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $30 - $150, depending upon preparation required.

1096<

METHYLENE BLUE ACTIVE SUBSTANCES (MBAS)

Parameter Group: General Organic

STORET Units: mg/ℓ

General: Certain solutes, even at low concentrations, have the property of lowering the surface tension or other interfacial properties of their solvents. Such solutes are known as surfactants or surface-active agents. They are found in soaps, detergents, emulsifiers, wetting agents, and penetrants, with the most common use, by far, being in synthetic detergents where they may account for 20% - 40% of the product in active form alone. The specific surfactant most widely used until recently is the group of alkyl benzene sulfonates (ABS), which persist in sewage and streams in biologically active solution without appreciable decomposition from either treatment processes or natural purification, being largely immune to biological degradation. Today, the more biodegradable linear alkyl sulfonate (LAS) has essentially replaced ABS on the surfactant market so that measurable surface-active agents will probably be LAS type materials. In addition to foaming problems, anionic surfactants may enhance slime growth, inhibit the growth of nitrifying bacteria, delay gas exchange with the atmosphere, and interfere with the uptake of oxygen. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 250 mℓ

Measurement: Anionic-type surfactants react with methylene blue dye in aqueous solution to form a blue colored salt which is extractable with chloroform, its color intensity being proportional to the concentration of MBAS. The more complicated, time consuming, and expensive tests for specific substances (e.g., LAS) are not usually warranted. The method is recommended for determination in drinking waters, surface waters, domestic and industrial wastes. It is not applicable to measurement of surfactant-type materials in saline waters. Chlorides at concentration of about 1,000 mg/ℓ show a positive interference, but the degree of interference has not been quantified. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: A sample of filtered river water, spiked with 2.94 mg LAS/ℓ was analyzed in 110 laboratories with a relative standard deviation of 9.1% and a relative error of 1.4%. In similar analyses with a sample of tap water spiked with 0.48 mg LAS/ℓ, relative standard deviations and errors of 9.9% and 1.3% were obtained, and for a sample of distilled water spiked with 0.27 mg LAS/ℓ, the respective values were 14.8% and 10.6%.

Cost of Analysis: $10 - $15

1098<
MIREX

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Mirex, an organochlorine insecticide, is largely used to control the imported fire ant in the southeastern United States. Crayfish and channel catfish survival is affected by mirex in the water or by ingestion of the bait particles. Bioaccumulation is well established for a wide variety of organisms but the effect of this bioaccumulation on the aquatic ecosystem is unknown. There is evidence that mirex is very persistent in bird tissue. Considering the extreme toxicity and potential for bioaccumulation, every effort should be made to keep mirex bait particles out of water containing aquatic organisms. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 0.001 µg/ℓ for freshwater and marine aquatic life.

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50 to 100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for mirex. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 µg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration.

Cost of Analysis: $30 - $150, depending upon preparation required.

1099<

MOLYBDENUM

Parameter Group: Metals STORET Unit: µg/ℓ as Mo

General: Molybdenum occurs naturally as molybdenum sulfide and lead molybdate. Its chief use is in the production of alloy steels (especially corrosion-resistant stainless steels) where advantage is made of its marked passivity. Other possible sources include mining and ore processing operations, chemical production, some fertilizers, and metallurgical operations. Molybdenum has a relatively low order of toxicity. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 313.3 nm. With the nitrous oxide-acetylene flame, interferences of calcium and other ions may be controlled by adding 1,000,000 µg/ℓ of a refractory metal such as aluminum. This should be done to both the samples and standards. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 300 µg/ℓ; its detection limit is 100 µg/ℓ. The optimum concentration range is 500-20,000 µg/ℓ. In a single laboratory, using a mixed industrial-domestic waste effluent at concentrations of 300, 1,500, and 7,500 µg Mo/ℓ, the relative standard deviations were 2.3%, 1.3%, and .93%, respectively. Recoveries at these levels were 100%, 96%, and 95%, respectively.

Cost of Analysis: $10 - $15

1100<
NAPHTHALENE

Parameter Group: STORET Units:

General: Naphthalene ($C_{10}H_8$) is the most abundant single constituent of coal tar. It is a white solid with the odor of moth balls. It is soluble in water at 20°C to the extent of about 30 mg/ℓ. The use of naphthalene in organic syntheses and dye manufacture is extensive, and hence it may occur in wastes from refineries, coal-tar plants, textile mills, and chemical industries. Lethal concentrations to fish are around 5-20 mg/ℓ. Fish tainting can occur at 1 mg/ℓ. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Not determined. Analyze promptly. Cool to 4°C.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100-1,000 mℓ

Measurement: The general procedure involves extraction and measurement with a gas chromatograph. Various cleanup techniques to remove interferences may be required depending upon other constituents in the sample. A skilled chemist or specialist will be required. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Detection limits in the 1-10 µg/ℓ range should be achievable. Precision and accuracy data are not available at this time.

Cost of Analysis: $40 - $60

1101<
NICKEL

Parameter Group: Metals STORET Units: µg/ℓ as Ni

General: Nickel principally occurs in nature as sulfide. Its main industrial use is in electroplating, alloying, coin making, and in alkaline storage batteries. Other potential sources include silver refineries, basic steel works and foundaries, motor vehicle and aircraft industries, and printing operations. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permit program. It is one of the Consent Decree pollutants.

Criterion: 0.01 of the 96-hour LC_{50} for freshwater and marine aquatic life.

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 232.0 nm. The 352.4 nm wavelength is less susceptible to nonatomic absorbance and may also be used. The calibration curve is more linear at this wavelength; however, there is some loss of sensitivity. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 150 µg/ℓ; its detection limit is 20 µg/ℓ. The optimum concentration range is 300-10,000 µg/ℓ. In a single laboratory, using a mixed industrial-domestic waste effluent at concentrations of 200, 1,000, and 5,000 µg Ni/ℓ, the standard deviations were ±0.011, ±0.02, and ±0.04, respectively. Recoveries at these levels were 100%, 97%, and 93%, respectively.

Cost of Analysis: $10 - $15

1102<

NITRILOTRIACETIC ACID (NTA)

Parameter Group: General
Organic

STORET Units: mg/ℓ

General: Nitrilotriacetic acid (NTA) is insoluble in water, but its tribasic salt is quite soluble. NTA has a strong affinity for iron, calcium, magnesium, and zinc, but its relative affinity for toxic metals such as cadmium and mercury is not known, nor have its chelating properties in complex ionic solutions been characterized. It has a potential large-scale use as a substitute for phosphates in detergents. No cases of acute human poisoning by NTA have been reported. It is biodegraded in the natural environment within 4 to 5 days; degradation is accelerated by biological waste treatment.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 50 mℓ

Measurement: The zinc-reagent method is often used. In this method, NTA refers to the tri-sodium salt of nitrilotriacetic acid. It is applicable to surface waters in the range of 0.5-10.0 mg/ℓ NTA. Cations, such as calcium, magnesium, zinc, copper, iron, and manganese, complex with NTA and give a negative interference. These ions are removed by batch treating samples with ion-exchange resin. At concentrations higher than expected in typical river waters, only zinc, copper, and iron were not completely removed with ion-exchange treatment.

Precision and Accuracy: In a single laboratory, using spiked surface water samples at concentrations of 0.5, 2, 6, and 10 mg/ℓ NTA, relative standard deviations were 3.4%, 7%, 1.7%, and 1.6%, respectively. In a single laboratory, using spiked surface water samples at concentrations of 1.0 and 7.5 mg/ℓ NTA, recoveries were 120% and 103%, respectively.

Cost of Analysis: $10 - $12

1103<

NITROBENZENE

Parameter Group: STORET Units:

General: Nitrobenzene ($C_6H_5NO_2$) is moderately soluble in water. It is used in the manufacture of analine, soaps, and shoe polishes. Nitrobenzene is an oily liquid and has an almond odor. A concentration of 0.03 mg/ℓ in water will produce a faint odor. The oral LD_{50} for rabbits is 700 mg/kg of body weight. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Not determined. Analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 200-1,000 mℓ

Measurement: No standard procedures have been developed. The methodology generally requires extraction, concentration, and gas chromatographic analysis. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Detection limits of 1 to 10 µg/ℓ should be achievable. Precision and accuracy data are not available at this time.

Cost of Analysis: $40 - $60

1104<

NITROGEN-AMMONIA

Parameter Group: Nitrogen STORET Units: mg/ℓ as N

General: Ammonia, one of the chemically interconvertible components of the nitrogen cycle, is naturally present in surface and ground water in concentrations from less than 0.01 to around 0.2 mg/ℓ as N in the absence of pollution. It is produced largely by the deamination of nitrogenous organic matter and the hydrolysis of urea. It may also result from the reduction of nitrate under anaerobic conditions. Other sources include the discharge of industrial wastes from chemical and gas plants, from ice plants, and where it is used in scouring and cleaning operations. There appears little physiological risk in palatable concentrations, the odor threshold being 0.037 mg/ℓ. Because it changes rapidly to nitrites and nitrates, ammonia is actually a fertilizer for most crops; ammonium salts constitute a major source of nitrogen fertilization. The toxicity of ammonia to fish is highly pH dependent. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Add 2 mℓ of concentrated H_2SO_4 or 40 mg $HgCl_2$/ℓ and store at 4°C. The use of mercuric chloride is discouraged whenever possible, however.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 400 mℓ

Measurement: The distillation procedure is recommended for the determination of ammonia-nitrogen. The method covers the range from about 0.05 to 1.0 mg/ℓ NH_3-N/ℓ for the colorimetric procedures, from 1.0 to 25 mg/ℓ for the titrimetric procedure, and from 0.05 to 1,400 mg/ℓ for the electrode method. A number of aromatic and aliphatic amines will cause turbidity upon the addition of Nessler reagent. Cyanate will hydrolyze to some extent. Volatile alkaline compounds may cause an off-color upon Nesslerization. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Precision and accuracy are highly dependent upon concentration, other constituents present, and the finish method. Relative standard deviations may range from around 4% to 40% and relative errors from under 1% to over 15%.

Cost of Analysis: $10 - $12

1105<

NITROGEN, KJELDAHL

Parameter Group: Nitrogen STORET Units: mg/ℓ as N

General: Kjeldahl nitrogen is defined as the sum of free-ammonia and organic nitrogen compounds which are converted to ammonium sulfate $(NH_4)_2SO_4$ under conditions of digestion. Organic nitrogen includes natural materials such as proteins and peptides, nucleic acids and urea, and numerous synthetic organic substances. The organic nitrogen concentrations of water and wastewater may vary from less than 0.01 mg/ℓ for the former to over 10 mg/ℓ for the latter. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Add 2 mℓ of concentrated H_2SO_4 to pH <2 or 40 mg $HgCl_2$/ℓ and store at 4°C. The use of mercuric chloride is discouraged whenever possible, however.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 500 mℓ

Measurement: In the Kjeldahl nitrogen determination the sample is heated in the presence of concentrated sulfuric acid, K_2SO_4, and $HgSO_4$ and evaporated until SO_3 fumes are obtained and the solution becomes colorless or pale yellow. The residue is cooled, diluted, and is treated and made alkaline with a hydroxide-thiosulfate solution. The ammonia is distilled and determined by either the titrimetric method, the Nesslerization method, or the potentiometric method. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Thirty-one analysts in twenty laboratories analyzed natural water samples containing exact increments of organic nitrogen. At the 0.2-0.3 mg/ℓ as N concentration level the relative standard deviation and error were around 90% and 10%, respectively. At around 4 mg/ℓ as N they were about 25% and 1%, respectively.

Cost of Analysis: $15 - $20

1106<

NITROGEN, NITRATE

Parameter Group: Nitrogen STORET Units: mg/ℓ as N

General: Nitrate, one of the chemically interconvertible compounds of the nitrogen cycle, occurs in trace quantities in surface water and in small amounts in fresh domestic wastewater. It is seldom abundant, since it serves as an essential nutrient for all types of plants. Some ground water may contain high levels of nitrate (as a result of leachings from cesspools or excess applications of fertilizers, etc.) due to the lack of photosynthetic action. There has been no reporting of physiological harm at concentrations of less than 10 mg/ℓ as N. Nitrates are injurious for certain industrial uses (e.g., fabric dyeing, fermentative processes). High nitrate concentrations stimulate the growth of plankton and aquatic weeds and accelerate eutrophication. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Add 2 mℓ concentrated H_2SO_4/ℓ to ph <2 or 40 mg $HgCl_2/\ell$ and store at 4°C. The use of mercuric chloride is discouraged whenever possible, however.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 100 mℓ

Measurement: The brucine method is recommended in the range from 0.1 to 2 mg NO_3-N/ℓ for determination in drinking, surface, and saline waters, domestic and industrial wastes. Dissolved organic matter will cause an off color. The effect of salinity is eliminated by the addition of sodium chloride to the blanks, standards, and samples. All strong oxidizing or reducing agents interfere. Residual chlorine interference is eliminated by the addition of sodium arsenite. Ferrous and ferric iron and quadrivalent manganese give slight positive interferences. Uneven heating of the samples and standards during the reaction time will result in erratic values. The cadmium reduction method may also be used; see discussion under Nitrogen, Nitrate-Nitrite. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Five synthetic samples containing nitrate and other constituents were analyzed in 50 laboratories at concentrations of 0.05, 0.5, and 5 mg/ℓ as N; relative standard deviations were 66.7%, 14.4%, and 15.4% and relative errors were 7.6%, 0.6%, and 4.5%, respectively.

Cost of Analysis: $10 - $12

1108<

NITROGEN, NITRATE-NITRITE

Parameter Group: *Nitrogen* STORET Units: mg/ℓ as N

General: See discussions under nitrate and nitrite. The combined test is less expensive than making individual determinations and provides a determination of total oxidized nitrogen. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Store at 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 100 mℓ

Measurement: The cadmium reduction method is recommended for the determination of nitrite and nitrate combined in drinking, surface, and saline waters, domestic and industrial wastes. Buildup of suspended matter in the reduction column will restrict sample flow. Low results might be obtained for samples that contain high concentrations of iron, copper, or other metals. EDTA is added to the samples to eliminate this interference. Samples that contain large concentrations of oil and grease will coat the surface of the cadmium. This interference is eliminated by pre-extracting the sample with an organic solvent. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The applicable range of this method is 0.01 to 1.0 mg/ℓ nitrate-nitrite nitrogen. In a single laboratory, using sewage samples at concentrations of 0.04, 0.24, 0.55, and 1.04 mg NO_3 + NO_2-N/ℓ, the relative standard deviations were 12.5%, 1.6%, .9%, and .9%, respectively, while recoveries were 100%, 102%, and 100%, respectively.

Cost of Analysis: $10 - $15

1109<

NITROGEN, NITRITE

Parameter Group: Nitrogen STORET Units: mg/ℓ as N

General: Nitrite, one of the chemically interconvertible compounds of the nitrogen cycle, occurs in the oxidation of ammonia to nitrate and in the reduction of nitrate. This oxidation and reduction may occur in wastewater treatment plants, water distribution systems, and natural waters. In conjunction with ammonia and nitrate, nitrites are often indicative of water pollution. They exhibit the same deleterious effects as nitrates except at lower concentrations, e.g., no physiological harm under 2 mg/ℓ as N. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Store at 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 50 mℓ

Measurement: The diazotization method is recommended for the determination of nitrite nitrogen in the range from 0.01 to 1.0 mg NO_2-N/ℓ. The diazonium compound formed by diazotation of sulfanilamide by nitrite in water under acid conditions is coupled with N-(1-naphthyl)-ethylenediamine to produce a reddish-purple color which is read in a spectrophotometer at 540 nm. The presence of strong oxidants or reductants to the samples will affect the nitrite concentrations. High alkalinity (>600 mg/ℓ) will give low results due to a shift in pH. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Precision and accuracy data are not available.

Cost of Analysis: $5 - $12

1110<

NITROPHENOLS

Parameter Group: STORET Units:

General: Nitrophenols include 2, 4-dinitrophenol; dinitrocresol, 2-nitrophenol, 4-nitrophenol, and 4, 6-dinitro-o-cresol. Metanitrophenol is highly soluble in cold water, p-nitrophenol moderately so, and o-nitrophenol only sparingly soluble. The ortho isomer is used in chemical manufacturing. Minimum lethal doses to fish vary with isomer, species, and other water constituents (e.g., hard water concentrations may be 10 times greater than those of distilled water). This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Not determined. Analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 200-1,000 mℓ

Measurement: No standard procedures have been developed. The methodology generally requires extraction, concentration, and gas chromatographic analysis. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Detection limits of 1 to 10 µg/ℓ should be achievable. Precision and accuracy data are not available at this time.

Cost of Analysis: $40 - $60

1111<

OIL AND GREASE

Parameter Group: General
Organic

STORET Units: mg/ℓ

General: Oils and grease are not definitive chemical categories but include thousands of organic compounds with varying physical, chemical, and toxicological properties. Grease and oil include hydrocarbons, fatty acids, soaps, fats, waxes, and oils. The three major industrial sources of oily waste are the petroleum industry, metals manufacture and machining, and food processors. Field and laboratory evidence have demonstrated both acute lethal toxicity and long-term sublethal toxicity of oils to aquatic organisms. Bioaccumulation of petroleum products presents two especially important public health problems: (1) the tainting of edible, aquatic species, and (2) the possibility of edible marine organisms incorporating the high boiling, carcinogenic polycyclic aromatics in their tissues. The direct effects of aquatic oil pollution on man are minimal. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criteria: For domestic water supply: Virtually free from oil and grease, particularly from the tastes and odors that emanate from petroleum products.

For aquatic life:

- 0.01 of the lowest continuous flow 96-hour LC_{50} to several important freshwater and marine species, each having a demonstrated high susceptibility to oils and petrochemicals.
- Levels of oils or petrochemicals in the sediment which cause deleterious effects to the biota should not be allowed.
- Surface waters shall be virtually free from floating non-petroleum oils of vegetable or animal origin, as well as petroleum-derived oils.

Preservation Method: Analyze as soon as possible. If storage is required, cool to 4°C, add H_2SO_4 to pH <2.

Maximum Holding Time: 24 hours

Container Type: Glass

Sample Volume Required: 1,000 mℓ

Measurement: The Soxhlet extraction method is recommended when relatively polar, heavy petroleum fractions are present. The method is applicable to the determination of relatively non-volatile hydrocarbons, vegetable oils, animal fats, waxes, soaps, and greases. The separatory funnel extraction method can also be used. The infrared method is applicable for measurement of most light petroleum fuels. The Soxhlet extraction and separatory funnel extraction methods are not applicable to the light hydrocarbons that volatize at temperatures below 70°C. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The three oil and grease methods were tested by a single laboratory on a sewage. The Soxhlet extraction method determined the oil and grease level in the sewage to be 14.8 mg/ℓ. When 1-liter portions of the sewage were dosed with 14.0 mg of a mixture of #2 fuel oil and Wesson oil, the recovery was 88% with a standard deviation of 1.1 mg. The separatory funnel extraction method determined the oil and grease level in the sewage to be 12.6 mg/ℓ. When 1-liter portions of the sewage were dosed with 14.0 mg of a mixture of #2 fuel oil and Wesson oil, the recovery was 93% with a standard deviation of 0.9 mg. The infrared method determined the oil and grease level in the sewage to be 17.5 mg/ℓ. When 1-liter portions of the sewage were dosed with 14.0 mg of a mixture of #2 fuel oil and Wesson oil, the recovery was 99% with a standard deviation of 1.4 mg.

Cost of Analysis: $15 - $30

1113<

ORGANIC CARBON

Parameter Group: General Organic

STORET Units: mg/ℓ as C

General: Organic carbon is the carbon oxidized by dichromate or other strong oxidizing agents, the most common measurement being total organic carbon (TOC). As in the case of BOD, TOC is a measure of a significant aspect of the strength of a discharge but is not a pollutant per se. The value of TOC usually falls below the true concentration of organic contaminants because other constituent elements are excluded. TOC is a more direct expression of the organic chemical content of water than either the BOD or COD tests and is faster and more convenient. It is often used, after an empirical relationship has been established, to estimate BOD or COD. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C. Add H_2SO_4 to pH <2.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass (brown glass preferred)

Sample Volume Required: 25 mℓ

Measurement: The combustion-infrared method is recommended. The method is applicable to measurement of organic carbon above 1 mg/ℓ. Carbonate and bicarbonate carbon represent an interference under the terms of this test and must be removed or accounted for in the final calculation. Instrument manufacturer's directions must be followed. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The difficulty of sampling particulates limits the precision to approximately 5 to 10% or higher. On clear or filtered samples, the precision may approach 1 to 2%. A distilled water solution containing 107 mg/ℓ of oxidizable organic compounds was analyzed by 28 analysts in 21 laboratories with a relative standard deviation of 7.6% and a relative error of 1.01%.

Cost of Analysis: $12 - $15

1114<
PARATHION

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Parathion is the organophosphorus insecticide $C_{10}H_{14}O_5NPS$. It is a yellow liquid that is insoluble in water or kerosene but freely soluble in alcohols and aromatic hydrocarbons. It is most commonly applied to row and orchard crops. Few chronic exposure data are available for aquatic organisms. At high concentrations of parathion, deformities, tremors, convulsions, hypersensitivity, hemorrhages were evident in bullheads. Inhibition of cholinesterase enzymes is the established mode of physiological action of parathion. Parathion has been found acutely toxic to aquatic invertebrates. The half-life of parathion in river water (pH 7.3-8.0) is one week. The estimated fatal dose for a 70-kg man is 0.1 gram. The acute oral LC_{50} for rats ranges from 3,000 to 15,000 µg/kg of body weight. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 0.04 µg/ℓ for freshwater and marine aquatic life.

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100 mℓ or more

Measurement: The use of co-solvent extraction, column chromatography and liquid-liquid partition, and detection and measurement accomplished by flame photometric gas chromatography using a phosphorus specific filter is recommended for parathion. Great care must be exercised in the selection and use of methods to minimize interferences, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but is usually 0.010 µg/ℓ or higher. Sensitivity is typically 1 µg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: ·$30 - $150, depending upon preparation required.

1115<

PCNB

Parameter Group: STORET Units:

General: Pentachloronitrobenzene (PCNB) is an organochlorine insecticide. It is used as an agricultural fungicide. It is soluble in carbon disulfide, benzene, and chloroform. It is practically insoluble in water and cold alcohol.

Criterion: Not established

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for PCNB. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person).

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 µg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration.

Cost of Analysis: $30 - $150, depending upon preparation required

1116<

PENTACHLOROPHENOL

Paramater Group: Pesticides STORET Units: µg/ℓ

General: Pentachlorophenol (C_6HCl_5O) is a crystalline material only slightly soluble in water but freely soluble in alcohol, ether, and benzene. However, its sodium salt is highly soluble in water. Pentachlorophenol possesses bactericidal, herbicidal, insecticidal, fungicidal, and molluscicidal properties. In concentrated doses, it causes lung, liver, and kidney damage to humans. In sea water, a concentration of 1.0 mg/ℓ of soidum pentachlorophenol prevents the attachment of marine fouling organisms in pipe and conduit. Its toxicity is highly dependent upon the vehicle in which it is administered. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Acidify to a pH of 4 with H_3PO_4. Add 1.0g $CuSO_4 \cdot 5H_2O/\ell$ to inhibit biodegradation of phenols. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Borosilicate glass

Sample Volume Required: 100-1,000 mg/ℓ or more depending upon initial concentration.

Measurement: The recommended method involves direct aqueous injection for the gas-liquid chromatographic determination of concentrates containing more than 1 mg/ℓ phenolic compounds. A flame-ionization detector is used for their individual measurement. Suspended matter may interfere by plugging the microsyringe. Interfering nonphenolic organic compounds may be removed by distillation. Steps should be taken to minimize or eliminate ghosting. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Few precision and accuracy data are available. Precision is very operator dependent. For example, total precision may be 2 to 5 times single operator precision values.

Cost of Analysis: $40 - $60

1117<

pH

Parameter Group: Physical STORET Units: Standard Units

General: The pH of a solution is expressed as the logarithm of the reciprocal of the hydrogen ion activity in moles per liter at a given temperature. The practical scale extends from 0 (very acidic) to 14 (very alkaline) with 7 corresponding to exact neutrality at 25°C. Whereas alkalinity and acidity are measures of the total resistance to pH change or buffering capacity of a sample, pH represents the free hydrogen ion activity not bound by carbonate or other bases. The pH of most natural waters falls in the range of 4 to 9 with the majority being slightly basic. Changes in the normal pH for a given water may indicate the discharge of alkaline or acidic wastes. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criteria:

- 5-9, domestic water supplies (welfare).
- 6.5 - 9.0, freshwater aquatic life.
- 6.5 - 8.5, marine aquatic life (within this range, pH should not be more than 0.2 unit outside the normally occurring range).

Preservation Methods: Analyze on site if at all possible. Otherwise, seal the sample container and cool to 4°C. Sample bottle should not be opened before analysis.

Maximum Holding Time: Any holding time beyond 6 hours should be reported with the measurement.

Container Type: Plastic or glass

Sample Volume Required: 25 to 100 mℓ

Measurement: Although pH can be measured colorimetrically, the method suffers from numerous interferences, deterioration of indicators and color standards, and limited indicator range. The glass electrode method is the standard technique, employing either a glass electrode in conjunction with a separate reference (constant potential) electrode, e.g., calomel, silver-silver chloride, or a combination electrode (glass and reference). The measurement is temperature-dependent. Oil and grease may coat the pH electrode and cause a sluggish response. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The precision and accuracy attainable will depend upon the type and condition of the water and the care used in standardization and operation. Precisions of ±0.02 pH and accuracies of ±0.05 pH are achievable, but ±0.1 pH represents the accuracy limit under normal conditions. Typical standard deviations are from 0.1 to 0.2 pH.

Cost of Analysis: $3

1119<

PHENOLICS

Parameter Group: General Organic

STORET Units: µg/ℓ

General: Phenols are hydroxy derivatives of benzene and its condensed nuclei. Phenolic compounds include a wide variety of organic chemicals and may arise from the distillation of coal and wood; from oil refineries; chemical plants; livestock dips; human and other organic wastes; hydrolysis, chemical oxidation, and microbial degradation of pesticides; and from naturally occurring sources and substances. Despite the fact that it is used as a bactericide, weak phenol solutions are decomposed by bacteria and biological action, rates typically exceeding 2,000 µg/ℓ per day in natural streams. Chlorination of water containing phenolic compounds produces odoriferous and objectionable tasting chlorophenols. The ingestion of concentrated solutions of phenol will result in severe pain, renal irritation, shock, and possibly death. A 1.5-gram dose may be fatal. Many of the phenolic compounds are more toxic than pure phenol, especially to lower life forms. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 1 µg/ℓ for domestic water supply (welfare), and to protect against fish flesh tainting.

Preservation Method: Analyze as soon as possible. Cool to 4°C. Add H_3PO_4 to pH <4 and 1.0g $CuSO_4$/ℓ.

Maximum Holding Time: 24 hours

Container Type: Glass only

Sample Volume Required: 500 mℓ

Measurement: The 4-aminoantipyrine (4-AAP) method with distillation is recommended and is applicable to the analysis of drinking, surface, and saline waters, domestic and industrial wastes. Phenolic materials react with 4-aminoantipyrine in the presence of potassium ferricyanide at a pH of 10 to form a stable reddish-brown colored antipyrine dye. The amount of color produced is a function of the concentration of the phenolic material. For most samples, a preliminary distillation is required to remove interfering materials. Gas chromatograph tests can be used to isolate specific compounds. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Using the extraction procedure for concentration of color, six laboratories analyzed samples at concentrations of 9.6, 48.3, and 93.5 µg/ℓ. Relative standard deviations were 10.3%, 6.4%, and 4.5%, respectively. The method must be regarded as an approximation representing the minimum amount of phenols present because the phenolic value varies with the types of phenols within a given sample. It is therefore impossible to express the accuracy of the method.

Cost of Analysis: $15 - $25

1121<

PHOSPHORUS (ALL FORMS)

Parameter Group: Phosphorus STORET Units: mg/l P

General: Phosphorus in its elemental form (yellow phosphorus) does not occur free in nature and is particularly toxic to animal life, being subject to bioaccumulation in much the same way as mercury. Phosphorus as phosphate is abundant in nature and also from the activities of man. Phosphates occur as a result of leaching from minerals and ores in natural processes of degradation, from agricultural drainage as one of the stabilized products of decomposition of organic matter, as a result of innumerable industrial discharges, from some treated cooling waters, and as a major element of municipal sewage. It is an essential nutrient for plant and animal growth. Major uses include fertilizers, detergents, and industrial chemicals. Organic phosphates are used extensively in pesticides. The chief deleterious effect of high concentrations is accelerated eutrophication. They also interfere with coagulation and removal of turbidity. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. Definitions of the various phosphorus forms are given below.

Total Phosphorus - all of the phosphorus present in the sample, regardless of form, as measured by the persulfate digestion procedure.

Total Orthophosphate - inorganic phosphorus in the sample as measured by the direct colorimetric analysis procedure.

Total Hydrolyzable Phosphorus - phosphorus in the sample as measured by the sulfuric acid hydrolysis procedure, and minus pre-determined orthophosphates. This hydrolyzable phosphorus includes polyphosphorus plus some organic phosphorus.

Total Organic Phosphorus - phosphorus (inorganic + oxidizable organic) in the sample measured by the persulfate digestion procedure, and minus hydrolyzable phosphorus and orthophosphate.

Dissolved Phosphorus - all of the phosphorus present in the filtrate of a sample filtered through a phosphorus-free filter of 0.45 micron pore size and measured by the persulfate digestion procedure.

Dissolved Orthophosphate - as measured by the direct colorimetric analysis procedure.

Dissolved Hydrolyzable Phosphorus - as measured by the sulfuric acid hydrolysis procedure and minus pre-determined dissolved orthophosphates.

Dissolved Organic Phosphorus - as measured by the persulfate digestion procedure, and minus dissolved hydrolyzable phosphorus and orthophosphate.

When sufficient amounts of phosphorus are present in the sample to warrant such consideration, the insoluble forms may be calculated as the total minus the dissolved fraction and reported as Insoluble Phosphorus, Insoluble Orthophosphate, Insoluble Hydrolyzable Phosphorus, or Insoluble Organic Phosphorus.

Criterion: 0.10 µg/ℓ yellow (elemental) phosphorus for marine or estuarine waters.

Preservation Method: Filter on site if dissolved determination is desired. Cool to 4°C. Analyze as soon as possible. Add 40 mg/ℓ mercuric chloride as a preservative if absolutely necessary, but its use is discouraged whenever possible.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 50 mℓ

Measurement: The persulfate digestion method is recommended. After digestion, determine the total orthophosphate in the sample by the direct colorimetric analysis procedure. High iron concentrations can cause precipitation of and subsequent loss of phosphorus. Mercury chloride interferes when the chloride level of the sample is low, <50 mg Cl/ℓ. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Natural water samples with an exact increment of organic phosphate were analyzed by 33 analysts in 19 laboratories. At around 0.1 and 0.8 mg/ℓ P, relative standard deviations were around 35% and 15%, respectively, and relative error ranges were 3-12% and 1-3%, respectively. Natural water samples with an exact increment of orthophosphate were analyzed by 26 analysts in 16 laboratories. At around 0.01 and 0.02 mg/ℓ P, relative standard deviations were around 28% and 6% respectively, and relative errors were around 5.5% and 2.3%, respectively.

Cost of Analysis: $10 - $15

1123<

PHTHALATE ESTERS

Parameter Group: General Organic

STORET Units: µg/ℓ

General: Phthalate esters include bis (2-ethylhexyl) phthalate, butyl benzyl phthalate, di-n-butyl phthalate, diethyl phthalate, and dimethyl phthalate and are organic compounds used as plasticizers, particularly in polyvinyl chloride plastics. The di-2-ethylhexyl and di-n-butyl phthalates are used as an orchard acaricide and insect repellent. Phthalate esters can be detrimental to aquatic organisms at low water concentrations. Ability to concentrate high levels from water and reproductive impairment in certain species are suggestive of potential environmental damage. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: 3 µg/ℓ for freshwater aquatic life.

Preservation Method: Not determined. Analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 200-1,000 mℓ

Measurement: No standard procedures have been developed. The methodology generally requires extraction, concentration, and gas chromatographic analysis. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Detection limits of 0.1 to 10 µg/ℓ should be achievable. Precision and accuracy data are not available at this time.

Cost of Analysis: $25 - $40

1124<

POLYCHLORINATED BIPHENYLS

Parameter Group: General Organic

STORET Units: µg/ℓ

General: Polychlorinated biphenyls (PCB's) are a class of compounds produced by the chlorination of biphenyls and are registered in the United States under the trade name Aroclor(R). PCB compounds are slightly soluble in water (25 to 200 µg/ℓ), soluble in lipids, oils, and organic solvents, and resistant to both heat and biological degradation. PCB's are relatively nonflammable, have useful exchange and dielectric properties, and were used principally in the electrical industry in capacitors and transformers. The acute and chronic effects of PCB's have been determined on a number of aquatic organisms. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants. A toxic effluent limitation has been prescribed for this parameter by the NPDES permits program.

Criterion:

- .001 µg/ℓ for freshwater and marine aquatic life and for consumers thereof
- Every reasonable effort should be made to minimize human exposure.

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100-1,000 mℓ

Measurement: The recommended gas chromatograph method covers the following PCB mixtures: Aroclors 1221, 1232, 1242, 1248, 1254, 1260, and 1016. It is an extension of the method for organochlorine pesticides - both the PCB's and the organochlorine pesticides may be determined on the same sample. They are co-extracted by liquid-liquid extraction and separated from one another prior to gas chromatographic determination. A combination of the standard Florisil column cleanup procedure and a silica gel microcolumn separation procedure are employed. Identification is made from gas chromatographic patterns obtained through the use of two or more unlike columns. Detection and measurement is accomplished using an electron capture, microcoulometric, or electrolytic conductivity

detector. Solvents, reagents, glassware, and other sample processing hardware may yield discrete artifacts and/or elevated baselines causing misinterpretation of gas chromatograms. All of these materials must be demonstrated to be free from interferences under the conditions of the analysis. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Analysis: The detection limit is approximately 1 µg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $45 to $50 for a scan and one compound
$95 to $100 for total PCB's

1126<

POLYNUCLEAR AROMATIC HYDROCARBONS

Parameter Group: STORET Units:

General: Polynuclear aromatic hydrocarbons include 1, 2-benzanthracene, 3, 4-benzopyrene, 3, 4-benzofluoranthene, 11, 12-benzofluoranthene, chrysene, acenapthylene, anthracene, 1, 12-benzoperylene, fluoroethane, phenanthrene, 1, 2:5, 6-dibenanthracene, indeno (1, 2, 3-C, D) pyrene, and pyrene. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Not determined. Analyze promptly. Cool to 4°C.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 1,000-4,000 mℓ

Measurement: Procedures for determination of polynuclear aromatic hydrocarbons involve extraction, thin layer chromatography, and fluorescence or UV absorption spectra. They require confirmation on wastewater. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Detection limits range from around 0.2 to 20 µg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $300 - $600

1127<

POTASSIUM

Parameter Group: Metals STORET Units: mg/ℓ as K

General: Potassium occurs in nature as chloride or sulfate in certain salt deposits, in common rocks (average of the solid earth shell is 2.6%) and minerals (e.g., feldspar, greensand, alunite, leucite), and is present in vegetation. It is one of the most active metals and, hence, is only found in the ionized or molecular form. Its salts are indispensable for fertilizers, some varieties of glass, and certain other purposes. All are highly soluble and uses include baking powders, effervescent antiacids, as a flux for silver solders, treating coal to prevent slag formation, tanning, soap manufacturing, in matches and explosives, pesticides, in wood industries, dyeing and bleaching cotton, paint and varnish removers, electroplating, photoengraving, lithography, photographic emulsions, table salt, disinfectants, and a host of other uses. Potassium is an essential nutritional element, but in excessive doses it acts as a cathartic. Its level of toxicity to fish and other aquatic life depends upon its form and the age and species involved. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or Pyrex

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 766.5 nm. Sodium may interfere if present at much higher levels than the potassium. This effect can be compensated by approximately matching the sodium content of the potassium standards with that of the sample. The flame photometric method is rapid, sensitive, and accurate but requires a special instrument and much preliminary work before samples can be run routinely. The colorimetric method is usually inadvisable for potassium levels below 10 mg/ℓ. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 0.04 mg/ℓ; its detection limit is 0.005 mg/ℓ. The optimum concentration range is 0.1-2 mg/ℓ. In a single laboratory, using distilled

water samples at concentrations of 1.6 and 6.3 mg/ℓ, the relative standard deviations were 13% and 8%, respectively. Recoveries at these levels were 103% and 102%. In a 33-laboratory test using a synthetic unknown at 3.1 mg/ℓ K, results from the flame photometric method yielded a relative standard deviation of 15.5% and a relative error of 2.3%.

Cost of Analysis: $5 - $10

1129<

RADIOACTIVITY (ALPHA AND BETA)

Parameter Group: Radiological STORET Units: Unspecified

General: Naturally occurring radioactivity in water is due to contact with mineral deposits; many springs and deep wells have high levels of radioactivity. Uranium, thorium, and radium and their long series of daughter products are the chief naturally occurring emitters of alpha and beta radiation. With the advent of nuclear science, man has produced a long series of radioactive products, including almost all of the elements in the periodic table. In addition to mining and separation operations, other manmade sources include the manufacture of nuclear weapons, nuclear reactors, the production of isotopes, and their use in medical therapy, research, and industrial processes and instrumentation. Radioactivity may be considered as an indestructable property from the viewpoint of man's inability to cancel or neutralize it by chemical or physical means. Gross alpha and beta activity measurements represent the best overall indicator of the presence of radioactive contamination in waters and the need for more specific determinations of the more hazardous radionuclides. The radioactivity of natural waters is usually in the 1 to 1,000 pCi/ℓ range but may reach 100,000 pCi/ℓ, and the radon (short-lived) content of some mineral springs has been found to be as high as 750,000 pCi/ℓ. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Preservatives may alter the distribution of radioactivity in a sample and should not be used until the sample is separated into suspended and dissolved fractions.

Maximum Holding Time: Unstated. Adsorption onto container surfaces represents the greatest problem.

Container Type: Plastic or glass

Sample Volume Required: 1,000 mℓ

Measurement: The internal proportional counter is the recommended instrument for counting gross beta radioactivity. With a Geiger counter, the alpha activity cannot be determined separately. Alpha counting efficiency in end-window counters may be very low. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: In a study of two sets of paired water samples containing known additions of radionuclides, 15 laboratories determined the gross alpha activity and 16 analyzed the gross beta activity. The average recoveries of added gross alpha activity were 86%, 87%, 84%, and 82%. The average recoveries of added gross beta activity were 99%, 100%, 100%, and 100%.

Cost of Analysis: $9 - $15

RADIUM 1131<

Parameter Group: STORET Units:

General: There are four naturally occurring radium isotopes: radium 223, radium 224, radium 226, and radium 228. Radium 226 has a half life of 1600 years. Ra-228 is a beta emitter; the others are alpha emitters. Although alpha particles cannot penetrate the skin, they are particularly dangerous when ingested and deposited within the body. The determination of radium by precipitation is a screening technique applicable in particular to drinking water. It includes all alpha emitting isotopes, and as long as concentrations are within standards for Ra-226, the need for examination by a more specific method is minimal. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: None

Maximum Holding Time: Unknown, but prompt analysis is recommended.

Container Type: Plastic or glass

Sample Volume Required: 1,000 mℓ

Measurement: The recommended method is the determination of radium by precipitation. It involves the alpha counting of a borium-radium sulfate precipitate that has been isolated from the sample and purified. The method is also applicable to sewage and industrial wastes, provided that steps are taken to destroy organic matter and eliminate other interfering ions. A counting instrument is required. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: In a 20-laboratory study involving the analysis of four samples for total radium, all four results from two laboratories and two results from a third had to be rejected as outliers. Of the remainder, recoveries averaged higher than 95%. At the 95% confidence level, the precision was around 30%.

Cost of Analysis: $40 - $50

1132<
RESIDUE, SETTLEABLE

Parameter Group: Solids STORET Units: mℓ/ℓ

General: Settleable residue (solids) which blankets the bottom of water bodies damage the invertebrate populations, block gravel spawning beds, and if organic, remove dissolved oxygen from overlying waters. They can interfere with recreation, navigation, fish and shellfish production, and destroy aesthetic values of water. They may decompose to produce putrefactive odors and may exude products of decomposition to overlying waters. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 1000 mℓ

Measurement: Settleable matter is measured volumetrically with an Imhoff cone. The practical lower limit of the determination is about 1 mℓ/ℓ/hr. For some samples, a separation of settleable and floating materials will occur. In such cases, the floating materials are not measured. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Precision and accuracy data are not available at this time.

Cost of Analysis: $3 - $5

1133<

RESIDUE, TOTAL

Parameter Group: Solids STORET Units: mg/ℓ

General: Total residue (total solids) refers to all the solid matter (suspended and dissolved) in water or wastewater and is the material left in a vessel after evaporation of a sample and its subsequent drying in an oven. Thus it is the sum of filterable and nonfilterable residue. Waters with high residue are generally of inferior palatability and may induce adverse reaction to transient consumers. Also see discussions of filterable and nonfilterable residue. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 7 days

Container Type: Plastic or resistant glass

Sample Volume Required: 100 mℓ

Measurement: A well mixed aliquot of the test sample is quantitatively transferred to a pre-weighed evaporating dish and evaporated to dryness at 103-105°C. The practical range of the determination is from 10 mg/ℓ to 20,000 mg/ℓ. Large, floating particles or submerged agglomerates (non-homogeneous materials) should be excluded from the test sample. Floating oil and grease, if present, should be included in the sample and dispersed by a blender device before aliquoting. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The practical upper limit for this determination is 20,000 mg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $3 - $15

1134

RESIDUE, TOTAL FILTERABLE

Parameter Group: Solids STORET Units: mg/ℓ

General: Total filterable residue (total dissolved solids) consists of inorganic salts, small amounts of organic matter, and dissolved materials. The principal inorganic anions dissolved in water include the carbonates, chlorides, sulfates and nitrates (principally in ground waters); the principal cations are sodium, potassium, calcium, and magnesium. Excess dissolved solids are objectionable in drinking water because of possible physiological effects, unpalatable mineral tastes, and higher costs because of corrosion or the necessity for additional treatment. Some communities use water containing up to 4,000 mg/ℓ for drinking purposes. There is no proof of beneficial or therapeutic value to mineral waters. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 250 mg/ℓ for chlorides and sulfates in domestic water supplies (welfare).

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 7 days

Container Type: Plastic or resistant glass

Sample Volume Required: 100 mℓ

Measurement: The recommended method is applicable to drinking, surface, and saline waters, domestic and industrial wastes. A well mixed sample is filtered through a standard glass fiber filter. The filtrate is evaporated and dried to constant weight at 180°C. Highly mineralized waters containing significant concentrations of calcium, magnesium, chloride and/or sulfate may be hygroscopic and will require prolonged drying, desiccation and rapid weighing. Samples containing high concentrations of bicarbonate will require careful and prolonged drying at 180°C to insure that all the bicarbonate is converted to carbonate. Too much residue in the evaporating dish will crust over and entrap water that will not be driven off during drying. Total residue should be limited to about 200 mg. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The practical range of the determination is 10 mg/ℓ to 20,000 mg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $3 - $15

1135<

RESIDUE, TOTAL NONFILTERABLE

Parameter Group: Solids STORET Units: mg/ℓ

General: Total nonfilterable residue (suspended solids) is the material retained on a standard glass fiber filter disk after filtration of a well mixed sample. In natural waters it consists of erosion silt, organic detritus, and plankton. The discharge of wastewater presents virtually unlimited possibilities. Total nonfilterable residue includes all settleable solids. It has varying effects upon water uses (apart from individual effects of the substances constituting the suspended solids). It is the most difficult parameter in terms of obtaining a representative sample from the bulk source and is used as a measure of treatment plant efficiency. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Should not reduce the depth of the compensation point for photosynthetic activity by more than 10% from the established norm - for aquatic life.

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 7 days

Container Type: Plastic or resistant glass

Sample Volume Required: 100 mℓ

Measurement: The recommended method involves filtering a well mixed sample through a standard glass fiber filter, and the residue retained on the filter is dried to constant weight at 103-105°C. Too much residue on the filter will entrap water and may require prolonged drying. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The practical range of the determination is 10 mg/ℓ to 20,000 mg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $3 - $15

1136<

RESIDUE, VOLATILE

Parameter Group: Solids STORET Units: mg/ℓ

General: The volatile components in the residue represent a rough indication of the amount of organic matter present. Since the result may reflect loss of water of crystallization, loss of volatile organic matter before combustion, incomplete oxidation of certain complex organics, and decomposition of mineral salts during combustion, it may not yield an accurate measure of organic carbon. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 7 days

Container Type: Plastic or resistant glass

Sample Volume Required: 100 mℓ

Measurement: The recommended method determines the weight of solid material combustible at 550°C. The residue obtained from the determination of total, filterable, or nonfilterable residue is ignited at 550°C in a muffle furnace. The loss of weight on ignition is reported as mg/ℓ volatile residue. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: A collaborative study involving three laboratories examining four samples by means of ten replicates showed a standard deviation of ±11 mg/ℓ at 170 mg/ℓ volatile residue concentration.

Cost of Analysis: $10 - $15

1137<

SELENIUM

Parameter Group: Metals STORET Units: µg/ℓ as Se

General: Selenium appears in the soil as basic ferric selenite, calcium selenate, and as elemental selenium. Selenium salts are used in many industries, including paint, pigment and dye producers, electronics, glass manufacture, insecticide sprays, electrical apparatus (rectifiers, semiconductors, photoelectric cells, etc.), rubber, and alloying. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criteria:

- 10 µg/ℓ for domestic water supply (health)
- For marine and freshwater aquatic life; 0.01 of the 96-hour LC_{50} as determined through bioassay using a sensitive resident species

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 50 mℓ

Measurement: The AA spectrophotometric gaseous hydride method is recommended using a wavelength of 196.0 nm. The method is applicable to most fresh and saline waters, in the absence of high concentrations of chromium, cobalt, copper, mercury, molybdenum, nickel and silver. The diaminobenzidine colorimetric method may also be used. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is approximately 2.5 µg/ℓ; its detection limit is 2 µg/ℓ. The working range of the method is 2-20 µg/ℓ. At a concentration of 10 µg/ℓ, the relative standard deviation is 11% and the relative error is 0.0%. Ten replicate solutions of selenium oxide at the 5, 10 and 15 µg/ℓ level were analyzed by a single laboratory. Relative standard deviations were 12%, 11%, and 19% with recoveries of 100%, 100%, and 101%.

Cost of Analysis: $15 - $40

1138<
SILICA

Parameter Group: Solids STORET Units: mg/ℓ as SiO_2

General: Silica is abundant in the earth's crust. It appears as an oxide in many rocks. The degradation of the rocks results in the presence of silica in natural waters. Silica is also widely used in industry and in water treatment. Silica in water forms silica and silicate scales in various equipments, particularly on high pressure steam turbine blades. In normally occurring concentrations it does not appear to cause adverse physiological effects. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 7 days

Container Type: Plastic or hard rubber

Sample Volume Required: 50-1000 mℓ

Measurement: Total silica is determined by a gravimetric method wherein silica acids are formed and precipitated, ignited, and the final determination made as the loss on volatilization. The recommended method for dissolved silica involves filtering a well-mixed sample through a 0.45μ membrane filter. The filtrate, upon the addition of molybdate ion in acidic solution, forms a greenish-yellow color complex proportional to the dissolved silica in the sample. The color complex is then measured spectrophotometrically. Excessive color and/or turbidity interfere. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Precision of the gravimetric method is approximately ±0.2 mg SiO_2. Photometric evaluations by the amino-naphthal-sulfuric acid procedure have an estimated precision of ±0.10 mg/ℓ in the range from 0 to 2 mg/ℓ. Photometric evaluations of the silica-molybdate color in the range from 2 to 50 mg/ℓ have an estimated precision of approximately 4% of the quantity of silica measured.

Cost of Analysis: $5 - $15

1139<

SILICON

Parameter Group: Solids STORET Units: µg/ℓ as Si

General: Silicon, the second most abundant element making up 26% of the earth's crust, is not found free in nature but occurs chiefly as the oxide (silica) in sand, quartz, agate, opal, etc., and as silicates in granite, feldspar, kaolinite, and other minerals. Silicon is one of man's most useful elements, with applications ranging from metallurgy to solid state electronics and the production of silicones, polymeric products ranging from liquids to hard glass-like solids with many beneficial properties. Silicon is also important in plant and animal life.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is often used, with a wavelength of 251.6 nm. Avoid any prolonged contact with glass.

Precision and Accuracy: The AA method sensitivity is 2,000 µg/ℓ; its detection limit is 300 µg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $10 - $20

1140<

SILVER

Parameter Group: Metals STORET Units: µg/ℓ as Ag

General: Silver ions cannot be expected to occur in significant concentrations in natural waters. As a solid metal, silver is used in the jewelry, silverware, metal alloy, and food processing industries. The solid metal produces very little soluble waste. Silver nitrate, which is soluble, is used in the porcelain, photographic, electroplating and ink manufacturing industries, and as an antiseptic. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criteria:

- 50 µg/ℓ for domestic water supply (health)
- For marine and freshwater aquatic life, 0.01 of the 96-hour LC_{50} as determined through bioassay using a sensitive resident species

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 328.1 nm. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 60 µg/ℓ; its detection limit is 10 µg/ℓ. The optimum concentration range is 100-4,000 µg/ℓ. At a concentration of 550 µg/ℓ, the relative standard deviation is 17.5%, and the relative error is 10.6%.

Cost of Analysis: $10 - $15

1141<

SILVEX (2, 4, 5-TP)

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Silvex, 2 (2, 4, 5-trichlorophenoxy) propionic acid, is a chlorinated phenoxy acid herbicide. It is used for weed control on land, and its esters and salts have been used as an aquatic herbicide in lakes, streams, and irrigation canals. It is slightly soluble in water and freely soluble in acetone and methyl alcohol. Silvex is reported to be slightly less toxic than 2, 4-D and 2, 4, 5-T type materials. Its acute oral LD_{50} to rats is 650,000 mg/kg of body weight. At a level of 2,000 µg/ℓ it has temporarily (e.g., 2 weeks) reduced the number of plankton in lakes, but fish are unaffected. Apparently the threshold of toxicity for fish is around 5,000 µg/ℓ. In some instances, however, fish have acquired an unpleasant, oily taste following exposure to Silvex. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: 10 µg/ℓ for domestic water supply (health).

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100 - 1,000 mℓ, depending on measurement method used.

Measurement: In the recommended method, chlorinated phenoxy acids and their esters are extracted from the acidified water sample with ethyl ether. The esters are hydrolyzed to acids, and extraneous organic material is removed by a solvent wash. The acids are converted to methyl esters which are extracted from the aqueous phase. The extract is cleaned up by passing it through a micro-adsorption column. Detection and measurement are accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography. Interferences may be high and varied and often pose great difficulty in obtaining accurate and precise measurement of chlorinated phenoxy acid herbicides. Organic acids, especially chlorinated acids, cause the most direct interference with the determination. Phenols including chlorophenols will also interfere with this procedure. The method is recommended for use only by an experienced pesticide analyst (or under the close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Sensitivity of the method is 1 µg/ℓ. Detection limits of 0.01 µg/ℓ or so may be achieved. Precision and accuracy data are not available at this time.

Cost of Analysis: $45 - $150, depending upon preparation required.

1143<

SODIUM

Parameter Group: Metals STORET Units: mg/ℓ as Na

General: Sodium is present in most natural waters and, as the cation of many salts used in industry, is one of the most common ions in industrial waters. A high sodium ratio has harmed soil permeability. Humans with certain diseases (cardiac, renal, and circulatory) require water with a low sodium concentration. Otherwise, taste considerations prevail as far as human ingestion is concerned. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Add HNO_3 to pH of 2.

Maximum Holding Time: 6 months

Container Type: Polyethylene bottles

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 589.6 nm. Low-temperature flames increase sensitivity by reducing the extent of ionization of this easily ionized metal. Ionization may also be controlled by adding potassium (1,000 mg/ℓ) to both standards and samples. The flame photometric method may also be used. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 0.015 mg/ℓ; its detection limit is 0.002 mg/ℓ. The optimum concentration range is 0.03-1.0 mg/ℓ. In a single laboratory, using distilled water samples at levels of 8.2 and 52 mg/ℓ, the relative standard deviations were 1.2% and 1.5%, respectively. Recoveries at these levels were 102% and 100%. In a 35-laboratory test using the flame photometric method on a synthetic unknown at 19.9 mg/ℓ Na, a relative standard deviation of 17.3% and a relative error of 4.0% were reported.

Cost of Analysis: $5 - $10

1144

SPECIFIC CONDUCTANCE

Parameter Group: Physical STORET Units: µmhos/cm @ 25°C

General: The determination of conductivity (specific electrical conductance) is a quick method for determining the ion concentration of water. The mobility of each of the various ions, their valences, and their actual and relative concentrations affect conductivity. The specific conductance of potable waters generally ranges from 50 to 1,500 µmhos/cm; for wastewaters it is highly variable and may be well in excess of 10,000 µmhos/cm. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 100 mℓ

Measurement: The specific conductance of a sample is measured by use of a self-contained conductivity meter, Wheatstone bridge-type or equivalent. Samples are preferably analyzed at 25°C. If not, temperature corrections are made and results reported at 25°C. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Typically, relative standard deviations of around 7 to 9% and relative errors from 2 to 5% are experienced.

Cost of Analysis: $3 - $5

STkONTIUM

Parameter Group: Radiological STORET Units: Unspecified

General: The radioactive nuclides of strontium produced in nuclear fission are Sr-89 and Sr-90. Strontium 90 is one of the most hazardous of all fission products. It has a half-life of 28 years. Strontium is concentrated in the bones if it is ingested. Ten percent of the occupational maximum concentration for Sr-90 in water is 100 pCi/ℓ. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established.

Preservation Method: None

Maximum Holding Time: Unknown, but prompt analysis is recommended.

Container Type: Plastic or glass

Sample Volume Required: Not determined

Measurement: The recommended method involves the use of a "carrier" which is inactive strontium ions in the form of strontium nitrate. Precipitation is used to obtain strontium carbonate from the strontium carrier and the radionuclide of strontium. It is dried to determine recovery of the carrier and then measured for radioactivity. Radioactive barium interferes in the determination of radioactive strontium. A counting instrument is required. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: In a study of two sets of paired water samples containing known additions of radionuclides, 12 laboratories determined the total radiostrontium and 10 laboratories determined Sr-90. The average recoveries of total radiostrontium from the four samples were 99%, 99%, 96%, and 93%. The average recoveries of added Sr-90 from the four samples were 90%, 96%, 80%, and 94%.

Cost of Analysis: $40 - $50

1146<
SULFATE

Parameter Group: General
Inorganic

STORET Units: mg/ℓ as SO_4

General: Sulfates occur naturally in waters as a result of leachings from gypsum and other common minerals or as the final oxidized stage of sulfides, sulfites, and thiosulfates having both mineral and organic origins. They may also be found in the wastes from numerous industries, including tanneries, sulfate pulp mills, textile mills, and other plants using sulfates or sulfuric acid. Excessive sulfates may exert a laxative action toward new users and cause taste problems, but such effects are not observed below 500 mg/ℓ. Limits for industrial users (especially sugar making) are much lower. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 7 days

Container Type: Plastic or glass

Sample Volume Required: 50 mℓ

Measurement: The turbidimetric method using a nephelometer is normally acceptable. The method is suitable for all concentration ranges of sulfate; however, in order to obtain reliable readings, use a sample aliquot containing not more than 40 mg/ℓ SO_4. Suspended matter and color interfere. Correct by running blanks from which the barium chloride has been omitted. The gravimetric method is recommended when results of the greatest accuracy are required. It is most accurate for sulfate concentrations above 10 mg/ℓ. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: A synthetic unknown sample containing 259 mg/ℓ sulfate, 108 mg/ℓ Ca, 82 mg/ℓ Mg, 3.1 mg/ℓ K, 19.9 mg/ℓ Na, 241 mg/ℓ chloride, 250 µg/ℓ nitrite N, 1.1 mg/ℓ nitrate N and 42.5 mg/ℓ total alkalinity (contributed by $NaHCO_3$) was analyzed by the gravimetric method, with a relative standard deviation of 4.7% and a relative error of 1.9% in 32 laboratories. Using the turbidimetric method in 19 laboratories, the relative standard deviation was 9.1% and the relative error, 1.2%.

Cost of Analysis: $4 - $12

1147<

SULFIDE

Parameter Group: General Inorganic

STORET Units: mg/ℓ as S

General: Sulfide is often present in groundwater and is common in some natural waters and sewage, coming in part from the anaerobic decomposition of organic matter. Sulfides are constituents of many industrial wastes, e.g., tanneries, paper mills, chemical plants, and gas works. It also occurs due to bacterial reduction of sulfates. The highly unpleasant taste and odor that results when sulfides occur in water make it unlikely that humans or animals will consume a harmful dose. Small traces of sulfide may be detrimental to some industrial uses. Sulfides are of little importance in irrigation waters. The sulfide ion readily reacts with free hydrogen ions in water to form hydrogen sulfide, which is very toxic, attacks metals directly, and indirectly causes serious corrosion to concrete sewers. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Add 2 mℓ zinc acetate, fill bottle completely, and stopper.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 50 mℓ

Measurement: The titrimetric iodine method is recommended. It is applicable to the measurement of total and dissolved sulfides. Acid insoluble sulfides are not measured by this test. Reduced sulfur compounds, such as sulfite, thiosulfate and hydrosulfite, which decompose in acid may yield erratic results. Volatile iodine consuming substances will give high results. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Precision and accuracy data have not been determined.

Cost of Analysis: $5 - $12

11.18<
SULFITE

Parameter Group: General Inorganic

STORET Units: mg/ℓ as SO_3

General: Sulfite may occur in certain industrial wastes but is most commonly found in boilers and boiler feedwater to wnich sodium sulfite has been added to reduce dissolved oxygen to a minimum and prevent corrosion. It is thought that a high concentration of sulfite in water may cause exema. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 50 mℓ

Measurement: The recommended method has a minimum detectable limit of 2-3 mg/ℓ SO_3. An acidified sample containing an indicator is titrated with a standard potassium iodide-iodate titrant to a faint permanent blue end point. The temperature of the sample must be below 50°C. Oxidizable substances, such as organic compounds, ferrous, iron and sulfide are positive interferences. Nitrite gives a negative interference by oxidizing sulfite when the sample is acidified. Copper and possibly other metals catalyze the oxidation of sulfite. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Precision and accuracy data are not available.

Cost of Analysis: $5 - $12

1149<

2, 4, 5-T

Parameter Group: Pesticides STORET Units: µg/ℓ

General: 2, 4, 5-T (2, 4, 5-trichlorophenoxyacetic acid) is the chlorinated phenoxy acid herbicide $C_8H_5Cl_3O_3$. It is a crystalline substance, almost insoluble in water, but soluble in alcohol. It is a plant hormone. The estimated lethal dose for a 90-kg man is 54 grams. The acute oral LD_{50} to rats is 300,000 mg/kg of body weight. 2, 4, 5-T forms phenol as a breakdown product. Toxicity data for aquatic life are sparse. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 100-1,000 mℓ, depending on measurement method used.

Measurement: In the recommended method, chlorinated phenoxy acids and their esters are extracted from the acidified water sample with ethyl ether. The esters are hydrolyzed to acids and extraneous organic material is removed by a solvent wash. The acids are converted to methyl esters which are extracted from the aqueous phase. The extract is cleaned up by passing it through a micro-adsorption column. Detection and measurement are accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography. Interferences may be high and varied and often pose great difficulty in obtaining accurate and precise measurement of chlorinated phenoxy acid herbicides. Organic acids, especially chlorinated acids, cause the most direct interference with the determination. Phenols including chlorophenols will also interfere with this procedure. The method is recommended for use only by an experienced pesticide analyst (or under the close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Sensitivity of the method is 1 µg/ℓ. Detection limits of 0.002 µg/ℓ or so may be achieved. Precision and accuracy data are not available at this time.

Cost of Analysis: $45 - $150, depending upon preparation required.

1150<

TEMPERATURE

Parameter Group: Temperature STORET Units: °C

General: Temperature changes in waters are due to natural climatic phenomena or the discharge of irrigation return flows and wastes, such as distilling effluents and cooling waters. The elevation of stream temperatures may contribute to decreased oxygen capacity, increased oxygen demand, anaerobic zones, and putrefaction of sludge deposits. Temperature is a significant factor for water treatment and many industrial uses, e.g., pulp and paper. Temperature also affects the value of numerous other water quality parameters. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criteria:

Freshwater Aquatic Life

For any time of year, there are two upper limiting temperatures for a location (based on the important sensitive species found there at that time):

1. One limit consists of a maximum temperature for short exposures that is time dependent and is given by the species-specific equation:

$$\text{Temperature}_{(C^{o})} = (1/b)\left(\log_{10}\left[\text{time}_{(\text{min})}\right]-a\right)-2^{\circ}C$$

where: $\log_{10}$ = logarithm to base 10 (common logarithm)

a = intercept on the "y" or logarithmic axis of the line fitted to experimental data and which is available from Appendix II-C, NAS, 1974 for some species.

b = slope of the line fitted to experimental data and available from Appendix II-C, NAS, 1974 for some species.

and

2. The second value is a limit on the weekly average temperature that:

a. In the cooler months (mid-October to mid-April in the north and December to February in the south) will protect against mortality of important species

if the elevated plume temperature is suddenly dropped to the ambient temperature, with the limit being the acclimation temperature minus 2°C when the lower lethal threshold temperature equals the ambient water temperature (in some regions this limitation may also be applicable in summer).

or

b. In the warmer months (April through October in the north and March through November in the south) is determined by adding to the physiological optimum temperature (usually for growth) a factor calculated as one-third of the difference between the ultimate upper incipient lethal temperature and the optimum temperature for the most sensitive important species (and appropriate life state) that normally is found at that location and time.

or

c. During reproductive seasons (generally April through June and September through October in the north and March through May and October through November in the south) the limit is that temperature that meets site-specific requirements for successful migration, spawning, egg incubation, fry rearing, and other reproductive functions of important species. These local requirements should supersede all other requirements when they are applicable.

or

d. There is a site-specific limit that is found necessary to preserve normal species diversity or prevent appearance of nuisance organisms.

Marine Aquatic Life

In order to ensure protection of the characteristic indigenous marine community of a water body segment from adverse thermal effects:

a. The maximum acceptable increase in the weekly average temperature due to artificial sources is 1°C (1.8°F) during all seasons of the year, providing the summer maxima are not exceeded; and

b. Daily temperature cycles characteristic of the water body segment should not be altered in either amplitude or frequency.

Summer thermal maxima, which define the upper thermal limits for the communities of the discharge area, should be established on a site-specific basis. Existing studies suggest the following regional limits:

	Short-term Maximum	Maximum True Daily Mean*
Sub-tropical Regions (south of Cape Canaveral and Tampa Bay, Florida, and Hawaii	32.2°C (90°F)	29.4°C (85°F)
Cape Hatteras, N.C., to Cape Canaveral, Florida	32.2°C (90°F)	29.4°C (85°F)
Long Island (south shore) to Cape Hatterras, N.C.	30.6°C (87°F)	27.8°C (82°F)

* (True Daily Mean = average of 24 hourly temperature readings.)

Baseline thermal conditions should be measured at a site where there is no unnatural thermal addition from any source, which is in reasonable proximity to the thermal discharge (within 5 miles) and which has similar hydrography to that of the receiving waters at the discharge.

Preservation Method: Determination on site

Maximum Holding Time: No holding

Container Type: Plastic or glass

Sample Volume Required: 1000 mℓ

Measurement: Temperature measurements may be made with any good grade of mercury-filled or dial type Celsius thermometer, or a thermistor. The measurement device should be checked against a precision thermometer certified by the National Bureau of Standards. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Precision and accuracy will depend upon instrument used.

Cost of Analysis: Not immediately determinable.

THALLIUM

Parameter Group: Metals STORET Units: µg/ℓ as Tl

General: Thallium salts are used as rodenticides and ant bait, dyes and pigments in fireworks, in optical glass, and as a depilatory. They are highly soluble in water and discharges are not likely to form precipitates. It is a cumulative poison, four times as toxic as arsenious oxide and affects the nervous system, causes muscular pain, endocrine disorders, and loss of hair. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 276.8 nm. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 500 µg/ℓ; its detection limit is 100 µg/ℓ. The optimum concentration range is 1,000-20,000 µg/ℓ. In a single laboratory, using a mixed industrial-domestic waste effluent at concentrations of 600, 3,000, and 15,000 µg/ℓ Tl, the relative standard deviations were 3%, 1.7%, and 1.3%, respectively. Recoveries at these levels were 100%, 98%, and 98%, respectively.

Cost of Analysis: $15 - $20

THRESHOLD ODOR

Parameter Group: Physical

STORET Units: Threshold Number

General: Odor is a quality factor that affects water in several ways including the acceptability of drinking water, tainting of fish, and the aesthetics of recreational waters. Odor can originate from industrial and municipal waste discharges and from natural sources such as decomposition of vegetable matter and living microscopic organisms. Odorous substances in water must be vaporizable in order to be smelled.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Glass

Sample Volume Required: 200 to 500 mℓ

Measurement: The consistent series method, in which the sample is divided to the point of the least definitely perceptible odor to each tester, is often used. Highly odorous samples are reduced in concentration proportionately before being tested. The method is applicable to samples ranging from nearly odorless natural waters to industrial wastes with threshold odor numbers in the thousands. Most tap waters and some waste waters are chlorinated. Dechlorination is achieved using sodium thiosulfate in exact stoichiometric quantity.

Precision and Accuracy: Precision and accuracy data are not available at this time.

Cost of Analysis: $5 - $10

TIN

Parameter Group: Metals STORET Units: µg/ℓ as Sn

General: Tin does not occur in natural waters. It is used in dyeing of fabrics, decorating porcelain, glassworks, fingernail polishes, some lacquers and varnishes, fungicides, insecticides, antihelminthics, antifoulant marine coatings and, of course, the tinning of vessels, especially foodstuff containers. Other sources include iron and steel production and power plant and industrial boilers. Tin is not believed to be toxic to man or other life forms. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 286.3 nm. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 4 mg/ℓ; its detection limit is 800 µg/ℓ. The optimum concentration range is 16,000-200,000 µg/ℓ. In a single laboratory, using a mixed industrial-domestic waste effluent at concentrations of 4,000, 20,000, and 60,000 µg/ℓ Sn, the relative standard deviations were 6.2%, 2.5%, and .8%, respectively. Recoveries at these levels were 96%, 101%, and 101%, respectively.

Cost of Analysis: $15 - $20

1156<

TITANIUM

Parameter Group: Metals STORET Units: µg/ℓ as Ti

General: Titanium ores and salts are abundantly distributed in the earth's crust, constituting from 0.5% to 10% of soils. The metal is used chiefly in alloying, and its salts are used in paint, paper, and dyeing industries, in the manufacture of electronic components, and in glass and ceramic production. There is little evidence of harm to life forms from titanium. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 365.3 nm. A number of elements increase the sensitivity of titanium. To control this problem, potassium (1,000 mg/ℓ) must be added to the standards and samples. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 2,000 µg/ℓ; its detection limit is 300 µg/ℓ. The optimum concentration range is 5,000-100,000 µg/ℓ. In a single laboratory, using a mixed industrial-domestic waste effluent at concentrations of 2,000, 10,000, and 50,000 µg/ℓ Ti, the relative standard deviations were 3.5%, 1.0%, and .8%, respectively. Recoveries at these levels were 97%, 91%, and 88%, respectively.

Cost of Analysis: $10 - $20

1157<

TOLUENE

Parameter Group: General Organic

STORET Units: µg/ℓ

General: Toluene ($C_6H_5CH_3$), a flammable liquid with an odor of benzene, is a constituent of coal tar. It is used in the manufacture of organic substances and as a solvent in the extraction of various principles from plants. Toluene is modestly soluble in water at normal temperatures. Its LD_{50} for rats is 7,000 mg/kg of body weight. Lethal concentrations to fish in clean water range from 10,000 to over 90,000 µg/ℓ depending upon temperature and species. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Not determined. Analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 200-1,000 mℓ

Measurement: Hexadecone extraction followed by gas chromatographic and mass spectrometric analysis is often used. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Detection limits should be around 2-10 µg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $15 - $30

TOTAL COLIFORM

Parameter Group: Bacteriologic STORET Units: See below

General: The coliform bacteria group as defined by the tests described herein includes organisms of diverse origins, including intermediate and Aerobactor aerogenes strains, which are usually of soil, vegetable, or other non-fecal origin; E. coli, which is usually but not always of fecal origin; and fecal coliform, which is a positive indication of the excrement of warm-blooded animals. The direct examination for the presence of a specific pathogen in water is not usually practicable for control purposes, and total coliform has been widely used as a microbiological indicator organism. The more specific fecal coliform indicator is gaining in popularity, however. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Cool to 4°C. Add a dechlorinating agent (e.g., sodium thiosulfate) if residual chlorine is present. Samples high in heavy metals should have a chelating agent (e.g., EDTA) added to reduce metal toxicity.

Maximum Holding Time: 6 hours (30 hours absolute maximum for potable water sample).

Container Type: Plastic or glass

Sample Volume Required: 100 mℓ

Measurement: The multiple tube fermentation technique, which defines the coliform group as all aerobic and facultative anaerobic, gram negative, rod-shaped, nonspore-forming bacteria that ferment lactose with gas formations within 48 hours at 35°C, is recommended. The simpler membrane filter technique, which defines the coliform group as the above bacteria that produce a dark colony with a metallic sheen within 24 hours on an Endo-type medium containing lactose, is also recommended, especially for nondrinking water tests. Results of the former are expressed statistically as the Most Probable Number (MPN), while the latter are expressed as number of colonies per 100 mℓ. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: Not applicable

Cost of Analysis: $10 - $12 MFT
$15 - $20 MPN

1159<

TOXAPHENE

Parameter Group: Pesticides STORET Units: µg/ℓ

General: Toxaphene is a chlorinated camphene insecticide. It is insoluble in water but highly soluble in organic solvents and oils. It has been reported that lakes treated with toxaphene concentrations ranging from 40 to 150 µg/ℓ remained toxic to fish for periods of a few months to five years. Bioconcentration accumulations of toxaphene of 5,000 to 21,000 times water concentrations have been observed in brook trout exposed only through water. Accumulation factors of 3,400 to 17,000 from aqueous solution have been reported for bacteria, algae, and fungi. Owing to the turpentine odor, it is not likely that toxic concentrations will be consumed by man or animals. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants. A toxic effluent limitation has been prescribed for this parameter by the NPDES permits program.

Criteria:

- 5 µg/ℓ for domestic supply (health)
- 0.005 µg/ℓ for freshwater and marine aquatic life

Preservation Method: Cool to 4°C; analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 50-100 mℓ or more

Measurement: The use of co-solvent extraction and detection and measurement accomplished by electron capture, microcoulometric or electrolytic conductivity gas chromatography is recommended for toxaphene under favorable conditions. Many interferences exist, especially PCB's, phthalate esters, and organophosphorus pesticides, and the method is only recommended for use by a skilled, experienced pesticide analyst (or under close supervision of such a person). For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The detection limit is affected by many factors, but usually falls in the 0.001 to 1 μg/ℓ range. Increased sensitivity is likely to increase interference. Typically, the percent recovery decreases with increasing concentration.

Cost of Analysis: $30 - $150, depending upon preparation required.

1161<

TRICHLOROETHYLENE

Parameter Group: STORET Units:

General: Trichloroethylene, a nonflammable liquid with a chloroform-like odor, is practically insoluble in water. It is used as a solvent and in solvent extraction by several industries, in degreasing, in the manufacture of chemicals and pharmaceuticals, and in dry cleaning. The oral LD_{50} for dogs is 5.86 g/kg of body weight. Concentrations of 55 mg/ℓ will stupify fish within 10 minutes. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Sample history must be known before any chemical or physical preservation steps can be applied to protect against phase separation. Fill the sample bottle completely and seal until analysis is performed. Do not refrigerate.

Maximum Holding Time: Unknown; preferably analyze within 1 hour.

Container Type: Borosilicate glass

Sample Volume Required: In excess of 200 mℓ

Measurement: In the recommended Bellar procedure the sample is stripped with an inert gas; volatiles are captured on an adsorbent trap and desorbed into a modified gas chromatograph equipped with a halogen-specific detector. Methodology should be checked for interferences, e.g., from bromine or iodine. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Sensitivity of the method is approximately 1,000 µg/ℓ. Detection limits of 0.2-3 µg/ℓ may be achieved. Precision and accuracy data are not available at this time.

Cost of Analysis: Around $60

1162<
TURBIDITY

Parameter Group: Physical

STORET Units: Formazin Turbidity Units

General: Turbidity is an optical property of water, reflecting its propensity for scattering light. From chlorination considerations, finished drinking waters typically have a maximum limit of 1 turbidity unit where the water enters the distribution system. Turbid water interferes with recreational use and aesthetic enjoyment of water. The less turbid the water, the more desirable it becomes for swimming and other water contact sports. See discussion for suspended solids. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Cool to 4°C.

Maximum Holding Time: 24 hours

Container Type: Plastic or glass

Sample Volume Required: 100 mℓ

Measurement: The recommended method is applicable to drinking, surface, and saline waters in the range of turbidity from 0 to 40 nephelometric turbidity units (NTU). The method is based upon a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension. The presence of floating debris and course sediments which settle out rapidly will give low readings. Finely divided air bubbles will affect the results in a positive manner. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: In a single laboratory, using surface water samples at levels of 26, 41, 75 and 180 NTU, the relative standard deviations were 2.3%, 2.3%, 1.6%, and 2.6%, respectively.

Cost of Analysis: $3 - $5

1163<

URANIUM

Parameter Group: Metals STORET Units: mg/ℓ

General: In addition to atomic energy applications, uranium is used in photography, glazing and painting porcelain, and in chemical processes. Many uranium salts are soluble in water. It has been reported that uranium and many of its salts are toxic; however, limited studies indicate that natural uranium, absorbed by people through the water and foodstuffs grown on land, may be a limiting factor in the incidence of leukemia. There is generally greater concern about the radiological hazards of uranium than about its chemical effects, however.

Criterion: Not established

Preservation Method: Analyze as soon as possible. Add HNO_3 to pH ≈2 and cool to 4°C.

Maximum Holding Time: Unknown

Container Type: Plastic or glass

Sample Volume Required: 50 mℓ

Measurement: The direct fluorometric method is often used. The concentration range is from 0.005 to 2.0 mg/ℓ. For higher concentrations, the extraction method may be used. The method involves the measurement of the fluorescence of a fused disk of sodium fluoride, lithium fluoride, and uranium compound exposed to ultraviolet light. The intensity of the fluorescence is proportional to the uranium concentration. Small quantities of cadmium, chromium, cobalt, copper, iron, magnesium, manganese, nickel, lead, platinum, silicon, thorium, and zinc interfere by quenching the uranium fluorescence and a purification or spiking method must be used. The AA method may also be used.

Precision and Accuracy: The single operator precision (S) at a uranium concentration of X mg/ℓ may be estimated from

$$\log (S-0.0016) = \log 0.129 + 1.20 \log X.$$

Cost of Analysis: $30 - $40

1164<

VANADIUM

Parameter Group: Metals STORET Units: µg/ℓ as V

General: Minerals containing vanadium are widespread in nature. In addition to its metallurgical uses, principally in steel alloying, its salts are used in the manufacture of glass, ceramics, ink, in photography, and in the dyeing and printing of fabrics. It is not considered toxic and, in fact, may play a beneficial role in reducing cholesterol, preventing heart disease and dental caries, and lowering the phospholipid content of the liver. Small quantities of vanadium may stimulate plant growth. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program.

Criterion: Not established

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 318.4 nm. High concentrations of aluminum and titanium increase the sensitivity of vanadium. This interference can be controlled by adding excess aluminum (1,000 mg/ℓ) to both samples and standards. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 800 µg/ℓ; its detection limit is 200 µg/ℓ. The optimum concentration range is 1,000-100,000 µg/ℓ. In a single laboratory, using a mixed industrial-domestic waste effluent at concentrations of 2,000, 10,000, and 50,000 µg/ℓ V, the relative standard deviations were 5%, 1%, and .4%, respectively. Recoveries at these levels were 100%, 95%, and 97%, respectively.

Cost of Analysis: $10 - $20

VINYL CHLORIDE

Parameter Group: STORET Units:

General: Vinyl chloride (chloroethene, CH_2:CHCl), a flammable gas with an ethereal odor, is only slightly soluble in water. It is prepared by catalytic addition of hydrogen chloride to acetylene or by pyrolysis of ethylene dichloride and is used chiefly for making vinyl resins. U.S. production exceeds 3 billion pounds annually. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.

Criterion: Not established

Preservation Method: Sample history must be known before any chemical or physical preservation steps can be applied to protect against phase separation. Fill the sample bottle completely and seal until analysis is performed. Do not refrigerate.

Maximum Holding Time: Unknown; preferably analyze within 1 hour.

Container Type: Borosilicate glass

Sample Volume Required: In excess of 200 mℓ

Measurement: In the recommended Bellar procedure the sample is stripped with an inert gas; volatiles are captured on an adsorbent trap and desorbed into a modified gas chromatograph equipped with a halogen-specific detector. Methodology should be checked for interferences, e.g., from bromine or iodine. A BAT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: Sensitivity of the method is approximately 1,000 µg/ℓ. Detection limits of 0.2-3 µg/ℓ may be achieved. Precision and accuracy data are not available at this time.

Cost of Analysis: Around $60

1166<

XYLENE

Parameter Group: General Organic

STORET Units: µg/ℓ

General: Xylene ($C_6H_4(CH_3)_2$), a flammable liquid, is a constituent of coal tar. It is used in the manufacture of dyes and organic substances, as a solvent, and as a cleaning agent. Xylene is insoluble in water. Its LD_{50} for white rats is 4.3g/kg of body weight. Lethal concentrations to fish range from 10,000 to 90,000 µg/ℓ depending upon temperature and species.

Criterion: Not established

Preservation Method: Not determined. Analyze promptly.

Maximum Holding Time: Unknown

Container Type: Borosilicate glass

Sample Volume Required: 200-1,000 mℓ

Measurement: Hexadecone extraction followed by gas chromatographic and mass spectrometric analysis is often used.

Precision and Accuracy: Detection limits should be around 2-10 µg/ℓ. Precision and accuracy data are not available at this time.

Cost of Analysis: $15 - $30

ZINC

Parameter Group: Metals STORET Units: µg/ℓ as Zn

General: Zinc is usually found in nature as the sulfide. Zinc is used in galvanizing and in the preparation of alloys for dye casting. Zinc is also used in brass and bronze alloys, slush castings, photoengraving, printing plates, silver and stainless steel tableware, viscose rayon yarn, wood pulp, and newsprint paper. Other sources include mining areas, paint pigments, cosmetics, pharmaceutics, insecticides, and many more. Zinc is an essential and beneficial element in human metabolism. Excessive amounts of zinc affect growth rates and decrease both the weight and fat content of the liver. This is a parameter which is regulated by BPT guidelines prescribed by the NPDES permits program. This parameter will be regulated by BAT guidelines prescribed by the NPDES permits program. It is one of the Consent Decree pollutants.
Zinc is a
Criteria:

- 5,000 µg/ℓ for domestic water supplies (welfare).
- For freshwater aquatic life, 0.01 of the 96-hour LC_{50} as determined through bioassay using a sensitive resident species.

Preservation Method: Analyze as soon as possible. If storage is necessary, add HNO_3 to pH <2.

Maximum Holding Time: 6 months

Container Type: Plastic or glass

Sample Volume Required: 100-200 mℓ

Measurement: The AA spectrophotometric method is recommended, using a wavelength of 213.9 nm. The air-acetylene flame absorbs about 25% of the energy at the 213.9-nm line. The sensitivity may be increased by the use of low-temperature flames. For BPT NPDES purposes the measurement of this parameter is prescribed by 40 CFR 136. A BPT NPDES method will be prescribed for this parameter in 40 CFR 136.

Precision and Accuracy: The AA method sensitivity is 20 µg/ℓ; its detection limit is 5 µg/ℓ. The optimum concentration range is 50-2,000 µg/ℓ. At a concentration of 500 µg/ℓ, the relative standard deviation is 8.2%, and the relative error is 0.4%.

Cost of Analysis: $10 - $15

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PART II

ENVIRONMENTAL PROTECTION AGENCY

■

WATER PROGRAMS

Guidelines Establishing Test Procedures for Analysis of Pollutants

Title 40—Protection of Environment

CHAPTER I—ENVIRONMENTAL PROTECTION AGENCY

SUBCHAPTER D—WATER PROGRAMS

PART 136—GUIDELINES ESTABLISHING TEST PROCEDURES FOR THE ANALYSIS OF POLLUTANTS

Notice was published in the FEDERAL REGISTER issue of June 29, 1973 (38 FR 17318) at 40 CFR 130, that the Environmental Protection Agency (EPA) was giving consideration to the testing procedures required pursuant to section 304(g) of the Federal Water Pollution Control Act Amendments of 1972 (86 Stat. 816, et seq., Pub. L. 92-500 (1972)) hereinafter referred to as the Act. These considerations were given in the form of proposed guidelines establishing test procedures.

Section 304(g) of the Act requires that the Administrator shall promulgate guidelines establishing test procedures for the analysis of pollutants that shall include factors which must be provided in: 1, any certification pursuant to section 401 of the Act, or 2, any permit application pursuant to section 402 of the Act. Such test procedures are to be used by permit applicants to demonstrate that effluent discharges meet applicable pollutant discharge limitations, and by the States and other enforcement activities in routine or random monitoring of effluents to verify effectiveness of pollution control measures.

These guidelines require that discharge measurements, including but not limited to the pollutants and parameters listed in Table I, be performed by the test procedures indicated; or under certain circumstances by other test procedures for analysis that may be more advantageous to use, when such other test procedures have the approval of the Regional Administrator of the Region where such discharge will occur, and when the Director of an approved State National Pollutant Discharge Elimination System (NPDES) Program (hereinafter referred to as the Director) for the State in which such discharge will occur has no objection to such approval.

The list of test procedures in Table I is published herein as final rulemaking and represents major departures from the list of proposed test procedures which was published in 38 FR 17318, dated June 29, 1973. These revisions were made after carefully considering all written comments which were received pertaining to the proposed test procedures. All written comments are on file and available for public review with the Quality Assurance Division, Office of Research and Development, EPA, Washington, D.C.

The principal revisions to the proposed test procedures are as follows:

1. Where several reliable test procedures for analysis are available from the given references for a given pollutant or parameter, each such test procedure has been approved for use for making the measurements required by sections 401 and 402 and related sections of the Act. Approved test procedures have been selected to assure an acceptable level of intercomparability of pollutants discharge data. For several pollutants and parameters it has still been necessary to approve only a single test procedure to assure this level of acceptability. This is a major departure from the proposed test procedures which would have required the use of a single reference method for each pollutant or parameter.

2. Under certain circumstances a test procedure not shown on the approved list may be considered by an applicant to be more advantageous to use. Under guidelines in §§ 136.4 and 136.5 it may be approved by the Regional Administrator of the Region where the discharge will occur, providing the Director has no objections. Inasmuch as there is no longer a single approved reference method against which a comparison can be made, the procedures for establishing such comparisons that were required by the proposed test procedures in § 130.4(b) have been deleted from this final guideline for test procedures for the analysis of pollutants.

3. A mechanism is also provided to assure national uniformity of such approvals of alternate test procedures for the analysis of pollutants. This is achieved through a centralized, internal review within the EPA of all applications for the use of alternate testing procedures. These will be reviewed and approved or disapproved on the basis of submitted information and other available information and laboratory tests which may be required by the Regional Administrator.

As deemed necessary, the Administrator will expand or revise these guidelines to provide the most responsive and appropriate list of test procedures to meet the requirements of sections 304(g), 401 and 402 of the Act, as amended.

These final guidelines establishing test procedures for the analysis of pollutants supersede the interim list of test procedures published in the FEDERAL REGISTER on April 19, 1973 (38 FR 9740) at 40 CFR Part 126 and subsequent procedures published on July 24, 1973 (38 FR 19894) at 40 CFR Part 124. Those regulations established interim test procedures for the submittal of applications under section 402 of the Act. Because of the importance of these guidelines for test procedures for the analysis of pollutants to the National Pollution Discharge Elimination System (NPDES), the Administrator finds good cause to declare that these guidelines shall be effective October 16, 1973.

JOHN QUARLES,
Acting Administrator.

OCTOBER 3, 1973.

PART 136—TEST PROCEDURES FOR THE ANALYSIS OF POLLUTANTS

Sec.

136.1 Applicability.
136.2 Definitions.
136.3 Identification of test procedures.
136.4 Application for alternate test procedures.
136.5 Approval of alternate test procedures.

AUTHORITY: Sec. 304(g) of Federal Water Pollution Control Act Amendments of 1972 86 Stat. 816, et seq., Pub. L. 92-500).

§ 136.1 Applicability.

The procedures prescribed herein shall, except as noted in § 136.5, be used to perform the measurements indicated whenever the waste constituent specified is required to be measured for:

(a) An application submitted to the Administrator, or to a State having an approved NPDES program, for a permit under section 402 of the Federal Water Pollution Control Act as amended (FWPCA), and,

(b) Reports required to be submitted by dischargers under the NPDES established by Parts 124 and 125 of this chapter, and,

(c) Certifications issued by States pursuant to section 401 of the FWPCA, as amended.

§ 136.2 Definitions.

As used in this part, the term:

(a) "Act" means the Federal Water Pollution Control Act, as amended, 33 U.S.C. 1314, et seq.

(b) "Administrator" means the Administrator of the U.S. Environmental Protection Agency.

(c) "Regional Administrator" means one of the EPA Regional Administrators.

(d) "Director" means the Director of the State Agency authorized to carry out an approved National Pollutant Discharge Elimination System Program under section 402 of the Act.

(e) "National Pollutant Discharge Elimination System (NPDES)" means the national system for the issuance of permits under section 402 of the Act and includes any State or interstate program which has been approved by the Administrator, in whole or in part, pursuant to section 402 of the Act.

(f) "Standard Methods" means *Standard Methods for the Examination of Water and Waste Water*, 13th Edition, 1971. This publication is available from the American Public Health Association, 1015 18th St. NW., Washington, D.C. 20036.

(g) "ASTM" means *Annual Book of Standards, Part 23, Water, Atmospheric Analysis, 1972*. This publication is available from the American Society for Testing and Materials, 1916 Race St., Philadelphia, Pennsylvania 19103.

(h) "EPA Methods" means *Methods for Chemical Analysis of Water and Wastes*, 1971, Environmental Protection Agency, Analytical Quality Control Laboratory, Cincinnati, Ohio. This publication is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (Stock Number 5501-0067).

§ 136.3 Identification of test procedures.

Every parameter or pollutant for which an effluent limitation is now specified pursuant to sections 401 and 402 of the Act is named together with test descriptions and references in Table I. The discharge parameter values for which reports are required must be de-

termined by one of the standard analytical methods cited and described in Table I, or under certain circumstances by other methods that may be more advantageous to use when such other methods have been previously approved by the Regional Administrator of the Region in which the discharge will occur, and providing that the Director of the State in which such discharge will occur does not object to the use of such alternate test procedures.

Under certain circumstances the Regional Administrator or the Director in the Region or State where the discharge will occur may determine for a particular discharge that additional parameters or pollutants must be reported. Under such circumstances, additional test procedures for analysis of pollutants may be specified by the Regional Administrator or Director upon the recommendation of the Director of the Methods Development and Quality Assurance Research Laboratory.

TABLE I—LIST OF APPROVED TEST PROCEDURES

Parameter and units	Method	References: Standard methods	ASTM	EPA methods
General analytical methods:				
1. Alkalinity as $CaCO_3$ mg $CaCO_3$/liter.	Titration: electrometric, manual or automated method—methyl orange.	p. 270	p. 143	p. 8. p. 9.
2. B.O.D. five day mg/liter.	Modified winkler or probe method	p. 489		
3. Chemical oxygen demand (C.O.D.) mg/liter.	Dichromate reflux	p. 498	p. 219	p. 17.
4. Total solids mg/liter	Gravimetric 103–105° C	p. 538		p. 280.
5. Total dissolved (filterable) solids mg/liter.	Glass fiber filtration 180° C			p. 278.
6. Total suspended (nonfilterable) solids mg/liter.	Glass fiber filtration 103–105° C	p. 537		p. 278.
7. Total volatile solids mg/liter.	Gravimetric 550° C	p. 536		p. 282.
8. Ammonia (as N) mg/liter.	Distillation—nesslerization or titration automated phenolate.			p. 134. p. 141.
9. Kjeldahl nitrogen (as N) mg/liter.	Digestion + distillation—nesslerization or titration utomated digestion phenolate.	p. 469		p. 149. p. 157.
10. Nitrate (as N) mg/liter.	Cadmium reduction; brucine sulfate, automated cadmium or hydrazine reduction.	p. 458 p. 461	p. 124	p. 170. p. 175. p. 185.
11. Total phosphorus (as P) mg/liter.	Persulfate digestion and single reagent (ascorbic acid), or manual digestion, and automated single reagent or stannous chloride.	p. 526 p. 532	p. 42	p. 236. p. 246. p. 259.
12. Acidity mg $CaCO_3$/liter	Electrometric end point or phenolphthalein end point.		p. 148	
13. Total organic carbon (TOC) mg/liter.	Combustion—infrared method [1]	p. 257	p. 702	p. 221.
14. Hardness—total mg $CaCO_3$/liter.	EDTA titration: automated colorimetric atomic absorption.	p. 179	p. 170	p. 76. p. 78.
15. Nitrite (as N) mg/liter.	Manual or automated colorimetric diazotization.			p. 165. p. 198.
Analytical methods for trace metals:				
16. Aluminum—total [2] mg/liter.	Atomic absorption	p. 210		p. 98.
17. Antimony—total [2] mg/liter.	Atomic absorption [4]			
18. Arsenic—total mg/liter.	Digestion plus silver diethyldithiocarbamate; atomic absorption. [3]	p. 65 p. 62		p. 13.
19. Barium—total [2] mg/liter.	Atomic absorption [4]	p. 210		
20. Beryllium—total [2] mg/liter.	Aluminon; atomic absorption	p. 67 p. 210		
21. Boron—total mg/liter	Curcumin	p. 69		
22. Cadmium—total [2] mg/liter.	Atomic absorption; colorimetric	p. 210 p. 422	p. 692	p. 101.
23. Calcium—total [2] mg/liter.	EDTA titration; atomic absorption	p. 84	p. 692	p. 102.
24. Chromium VI mg/liter.	Extraction and atomic absorption; colorimetric.	p. 429		p. 94.
25. Chromium—total [2] mg/liter.	Atomic absorption; colorimetric	p. 210 p. 430	p. 692 p. 403	p. 104.
26. Cobalt—total [2] mg/liter.	Atomic absorption [4]		p. 672	
27. Copper—total [2] mg/liter.	Atomic absorption; colorimetric	p. 210 p. 430	p. 692 p. 410	p. 106.
28. Iron—total [2] mg/liter	do	p. 210 p. 433	p. 692 p. 152	p. 108.
29. Lead—total [2] mg/liter	do	p. 210 p. 436	p. 692	p. 110.
30. Magnesium—total [2] mg/liter.	Atomic absorption; Gravimetric	p. 210 p. 416 p. 201	p. 692	p. 112.
31. Manganese—total [2] mg/liter.	Atomic absorption	p. 210	p. 692	p. 114.
32. Mercury—total mg/liter.	Flameless atomic absorption [5]			
33. Molybdenum—total [2] mg/liter.	Atomic absorption [4]			
34. Nickel—total [2] mg/liter.	Atomic absorption; colorimetric [4]	p. 443	p. 692	
35. Potassium—total [2] mg/liter.	Atomic absorption; colorimetric; flame photometric.	p. 283 p. 288	p. 336	p. 116.
36. Selenium—total mg/liter.	Atomic absorption [3]			
37. Silver—total [2]	Atomic absorption [4]	p. 210		
38. Sodium—total [2] mg/liter.	Flame photometric; atomic absorption	p. 317	p. 826	p. 118.
39. Thallium—total [2] mg/liter.	Atomic absorption [4]			
40. Tin—total [2] mg/liter	do			
41. Titanium—total mg/liter.	do			
42. Vanadium—total [2] mg/liter.	Atomic Absorption; [4] Colorimetric	p. 157		
43. Zinc—total [2] mg/liter	Atomic Absorption; Colorimetric	p. 210 p. 444	p. 692	p. 120.
Analytical methods for nutrients, anions, and organics:				
44. Organic nitrogen (as N) mg/liter.	Kjeldahl nitrogen minus ammonia nitrogen.	p. 468		p. 149.
45. Ortho-phosphate (as P) mg/liter.	Direct single reagent; automated single reagent or stannous chloride.	p. 532	p. 42	p. 233. p. 246. p. 259.
46. Sulfate (as SO_4) mg/liter.	Gravimetric; turbidimetric; automated colorimetric—barium chloranilate.	p. 331 p. 334	p. 51 p. 52	p. 266. p. 268.
47. Sulfide (as S) mg/liter	Titrimetric—iodine	p. 551		p. 294.
48. Sulfite (as SO_3) mg/liter.	Titrimetric; iodide-iodate	p. 337	p. 261	
49. Bromide mg/liter	do		p. 216	
50. Chloride mg/liter	Silver nitrate; mercuric nitrate; automated colorimetric-ferricyanide.	p. 96 p. 97	p. 23 p. 21	p. 29. p. 31.
51. Cyanide—total mg/liter.	Distillation—silver nitrate titration or pyridine pyrazolone colorimetric.	p. 347	p. 556	p. 41.
52. Fluoride mg/liter	Distillation—SPADNS	p. 171 p. 174	p. 191	p. 64.
53. Chlorine—total residual mg/liter.	Colorimetric; amperometric titration	p. 382	p. 223	
54. Oil and grease mg/liter.	Liquid-Liquid extraction with trichlorotrifluoroethane.	p. 254		
55. Phenols mg/liter	Colorimetric, 4 AAP	p. 502	p. 648	p. 232.
56. Surfactants mg/liter	Methylene blue colorimetric	p. 339	p. 619	p. 181.
57. Algicides mg/liter	Gas chromatography [6]			
58. Benzidine mg/liter	Diazotization—colorimetric [3]			
59. Chlorinated organic compounds (except pesticides) mg/liter.	Gas chromatography [6]			
60. Pesticides mg/liter	Gas chromatography [6]			
Analytical methods for physical and biological parameters:				
61. Color platinum-cobalt units or dominant wave-length, hue, luminance, purity.	Colorimetric; spectrophotometric	p. 160	p. 392	p. 26.
62. Specific conductance mho/cm at 25° C.	Wheatstone bridge	p. 323	p. 163	p. 284.
63. Turbidity jackson units.	Turbidimeter	p. 350	p. 467	p. 308.

See Note at end of Table I

Parameter and units	Method	References		
		Standard methods	AETM	EPA methods
64. Fecal streptococci bacteria number/100 ml.	MPN; membrane filter; plate count	p. 889 p. 890 p. 891		
65. Coliform bacteria (fecal) number/100 ml.	MPN: Membrane filter	p. 889 p. 884		
66. Coliform bacteria (total) number/100 ml.	....do	p. 884 p. 879		
Radiological parameters:				
67. Alpha—total pCi/liter	Proportional counter, scintillation counter	p. 898	p. 809	
68. Alpha—counting error pCi/liter.	....do	p. 898	p. 812	
69. Beta—total pCi/liter	Proportional counter†	p. 898	p. 478	
70. Beta—counting error pCi/liter.	....do	p. 898	p. 478	
71. Radium—total pCi/liter.	Proportional counter; scintillation counter	p. 611 p. 617	p. 674	

[1] A number of such systems manufactured by various companies are considered to be comparable in their performance. In addition, another technique, based on Combustion-Methane Detection, is also acceptable.

[2] For the determination of total metals the sample is not filtered before processing. Choose a volume of sample appropriate for the expected level of metals. If much suspended material is present, as little as 50-100 ml of well-mixed sample will most probably be sufficient. (The sample volume required may also vary proportionally with the number of metals to be determined.)

Transfer a representative aliquot of the well-mixed sample to a Griffin beaker and add 3 ml of concentrated distilled HNO_3. Place the beaker on a hotplate and evaporate to dryness making certain that the sample does not boil. Cool the beaker and add another 3 ml portion of distilled concentrated HNO_3. Cover the beaker with a watch glass and return to the hotplate. Increase the temperature of the hotplate so that a gentle reflux action occurs. Continue heating, adding additional acid as necessary until the digestion is complete, generally indicated by a light colored residue. Add (1:1 with distilled water) distilled concentrated HCl in an amount sufficient to dissolve the residue upon warming. Wash down the beaker walls and the watch glass with distilled water and filter the sample to remove silicates and other insoluble material that could clog the atomizer. Adjust the volume to some predetermined value based on the expected metal concentrations. The sample is now ready for analysis. Concentrations so determined shall be reported as "total".

[3] See D. C. Manning, "Technical Notes", Atomic Absorption Newsletter, Vol. 10, No. 6 p. 123, 1971. Available from Perkin-Elmer Corporation, Main Avenue, Norwalk, Connecticut 06852.

[4] Atomic absorption method available from Methods Development and Quality Assurance Research Laboratory, National Environmental Research Center, USEPA, Cincinnati, Ohio 45268.

[5] For updated method, see: Journal of the American Water Works Association 64, No. 1, pp. 20-25 (Jan. 1972) or ASTM Method D 3223-73, American Society for Testing and Materials Headquarters, 1916 Race St., Philadelphia, Pa. 19103.

[6] Interim procedures for algicides, chlorinated organic compounds, and pesticides can be obtained from the Methods Development and Quality Assurance Research Laboratory, National Environmental Research Center, USEPA, Cincinnati, Ohio 45268.

[7] Benzidine may be estimated by the method of M.A. El-Dib, "Colorimetric Determination of Aniline Derivatives in Natural Waters", El-Dib, M.A., Journal of the Association of Official Analytical Chemists, Vol. 54, No. 6, Nov., 1971, pp. 1383-1387.

†As a preceding measurement.

§ 136.4 Application for alternate test procedures.

(a) Any person may apply to the Regional Administrator in the Region where the discharge occurs for approval of an alternative test procedure.

(b) When the discharge for which an alternative test procedure is proposed occurs within a State having a permit program approved pursuant to section 402 of the Act, the applicant shall submit his application to the Regional Administrator through the Director of the State agency having responsibility for issuance of NPDES permits within such State.

(c) Unless and until printed application forms are made available, an application for an alternate test procedure may be made by letter in triplicate. Any application for an alternate test procedure under this subchapter shall:

(1) Provide the name and address of the responsible person or firm making the discharge (if not the applicant) and the applicable ID number of the existing or pending permit, issuing agency and type of permit for which the alternate test procedure is requested, and the discharge serial number.

(2) Identify the pollutant or parameter for which approval of an alternate testing procedure is being requested.

(3) Provide justification for using testing procedures other than those specified in Table I.

(4) Provide a detailed description of the proposed alternate test procedure, together with references to published studies of the applicability of the alternate test procedure to the effluents in question.

§ 136.5 Approval of alternate test procedures.

(a) The Regional Administrator of the region in which the discharge will occur has final responsibility for approval of any alternate test procedure.

(b) Within thirty days of receipt of an application, the Director will forward such application, together with his recommendations, to the Regional Administrator. Where the Director recommends rejection of the application for scientific and technical reasons which he provides, the Regional Administrator shall deny the application, and shall forward a copy of the rejected application and his decision to the Director of the State Permit Program and to the Director of the Methods Development and Quality Assurance Research Laboratory.

(c) Before approving any application for an alternate test procedure, the Regional Administrator shall forward a copy of the application to the Director of the Methods Development and Quality Assurance Laboratory for review and recommendation.

(d) Within ninety days of receipt by the Regional Administrator of an application for an alternate test procedure, the Regional Administrator shall notify the applicant and the appropriate State agency of approval or rejection, or shall specify the additional information which is required to determine whether to approve the proposed test procedure. Prior to the expiration of such ninety day period, a recommendation providing the scientific and other technical basis for acceptance or rejection will be forwarded to the Regional Administrator by the Director of the Methods Development and Quality Assurance Research Laboratory. A copy of all approval and rejection notifications will be forwarded to the Director, Methods Development and Quality Assurance Research Laboratory, for the purposes of national coordination.

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WEDNESDAY, DECEMBER 1, 1976

PART II:

ENVIRONMENTAL PROTECTION AGENCY

WATER PROGRAMS

Guidelines Establishing Test Procedures for the Analysis of Pollutants

Amendments

Title 40—Protection of Environment

CHAPTER I—ENVIRONMENTAL PROTECTION AGENCY

SUBCHAPTER D—WATER PROGRAMS

[FRL 630-4]

PART 136—GUIDELINES ESTABLISHING TEST PROCEDURES FOR THE ANALYSIS OF POLLUTANTS

Amendment of Regulations

On June 9, 1975, proposed amendments to the Guidelines Establishing Test Procedures for the Analysis of Pollutants (40 CFR 136) were published in the FEDERAL REGISTER (40 FR 24535) as required by section 304(g) of the Federal Water Pollution Control Act Amendments of 1972 (86 Stat. 816, et seq., Pub. L. 92-500, 1972) hereinafter referred to as the Act.

Section 304(g) of the Act requires that the Administrator shall promulgate guidelines establishing test procedures for the analysis of pollutants that shall include factors which must be provided in: (1) any certification pursuant to section 401 of the Act, or (2) any permit application pursuant to section 402 of the Act. Such test procedures are to be used by permit applicants to demonstrate that effluent discharges meet applicable pollutant discharge limitations and by the States and other enforcement activities in routine or random monitoring of effluents to verify compliance with pollution control measures.

Interested persons were requested to submit written comments, suggestions, or objections to the proposed amendments by September 7, 1975. One hundred and thirty-five letters were received from commenters. The following categories of organizations were represented by the commenters: Federal agencies accounted for twenty-four responses; State agencies accounted for twenty-six responses; local agencies accounted for seventeen responses; regulated major dischargers accounted for forty-seven responses; trade and professional organizations accounted for eight responses; analytical instrument manufacturers and vendors accounted for seven responses; and analytical service laboratories accounted for six responses.

All comments were carefully evaluated by a technical review committee. Based upon the review of comments, the following principal changes to the proposed amendments were made:

(A) *Definitions.* Section 136.2 has been amended to update references: Twenty commenters, representing the entire spectrum of responding groups pointed out that the references cited in §§ 136.2 (f), 136.2(g), and 136.2(h) were out-of-date; §§ 136.2(f), 136.2(g), and 136.2(h), respectively, have been amended to show the following editions of the standard references: "14th Edition of Standard Methods for the Examination of Water and Waste Water;" "1974 EPA Manual of Methods for the Analysis of Water and Waste;" and "Part 31, 1975 Annual Book of ASTM Standards."

(B) *Identification of Test Procedures.* Both the content and format of § 136.3, "Table I, List of Approved Test Procedures" have been revised in response to twenty-one comments received from State and local governments, major regulated dischargers, professional and trade associations, and analytical laboratories.

Table I has been revised by:

(1) The addition of a fourth column of references which includes procedures of the United States Geological Survey which are equivalent to previously approved methods.

(2) The addition of a fifth column of miscellaneous references to procedures which are equivalent to previously approved methods.

(3) Listing generically related parameters alphabetically within four subcategories: bacteria, metals, radiological and residue, and by listing these subcategory headings in alphabetic sequence relative to the remaining parameters.

(4) Deleting the parameter "Algicides" and by entering the single relevant algicide, "Pentachlorophenol" by its chemical name.

(C) *Clarification of Test Parameters.* The conditions for analysis of several parameters have been more specifically defined as a result of comments received by the Agency:

(1) In response to five commenters representing State or local governments, major dischargers, or analytical instrument manufacturers, the end-point for the alkalinity determination is specifically designated as pH 4.5.

(2) Manual digestion and distillation are still required as necessary preliminary steps for the Kjeldahl nitrogen procedure. Analysis after such distillation may be by Nessler color comparison, titration, electrode, or automated phenolate procedures.

(3) In response to eight commenters representative of Federal and State governments, major dischargers, and analytical instrument manufacturers, manual distillation at pH 9.5 is now specified for ammonia measurement.

(D) *New Parameters and Analytical Procedures.* Forty-four new parameters have been added to Table I. In addition to the designation of analytical procedures for these new parameters, the following modifications have been made in analytical procedures designated in response to comments.

(1) The ortho-tolidine procedure was not approved for the measurement of residual chlorine because of its poor accuracy and precision. Its approval had been requested by seven commenters representing major dischargers, State, or local governments, and analytical instrument manufacturers. Instead, the N,N-diethyl-p-phenylenediamine (DPD) method is approved as an interim procedure pending more intensive laboratory testing. It has many of the advantages of the ortho-tolidine procedure such as low cost, ease of operation, and also is of acceptable precision and accuracy.

(2) The Environmental Protection Agency concurred with the American Dye Manufacturers' request to approve its procedure for measurement of color, and copies of the procedure are now available at the Environmental Monitoring and Support Laboratory, Cincinnati (EMSL-CI).

(3) In response to three requests from Federal, State governments, and dischargers, "hardness," may be measured as the sum of calcium and magnesium analyzed by atomic absorption and expressed as their carbonates.

(4) The proposal to limit measurement of fecal coliform bacteria in the presence of chlorine to only the "Most Probable Number" (MPN) procedure has been withdrawn in response to requests from forty-five commenters including State pollution control agencies, permit holders, analysts, treatment plant operators, and a manufacturer of analytical supplies. The membrane filter (MF) procedure will continue to be an approved technique for the routine measurement of fecal coliform in the presence of chlorine. However, the MPN procedure must be used to resolve controversial situations. The technique selected by the analyst must be reported with the data.

(5) A total of fifteen objections, representing the entire spectrum of commenters, addressed the drying temperatures used for measurement of residues. The use of different temperatures in drying of total residue, dissolved residue and suspended residue was cited as not allowing direct intercomparability between these measurements. Because the intent of designating the three separate residue parameters is to measure separate waste characteristics (low drying temperatures to measure volatile substances, high drying temperatures to measure anhydrous inorganic substances), the difference in drying temperatures for these residue parameters must be preserved.

(E) *Deletion of Measurement Techniques.* Some measurement techniques that had been proposed have been deleted in response to objections raised during the public comment period.

(1) The proposed infrared spectrophotometric analysis for oil and grease has been withdrawn. Eleven commenters representing Federal or State agencies and major dischargers claimed that this parameter is defined by the measurement procedure. Any alteration in the procedure would change the definition of the parameter. The Environmental Protection Agency agreed.

(2) The proposed separate parameter for sulfide at concentrations below 1 mg/l, has been withdrawn. Methylene blue spectrophotometry is now included in Table I as an approved procedure for sulfide analysis. The titrimetric iodine procedure for sulfide analysis may only be used for analysis of sulfide at concentrations in excess of one milligram per liter.

(F) *Sample Preservation and Holding Times.* Criteria for sample preservation and sample holding times were requested by several commenters. The reference for sample preservation and holding time criteria applicable to the Table I parameters is given in footnote (1) of Table I.

(G) *Alternate Test Procedures.* Comments pertaining to § 136.4, Application for Alternate Test Procedures, included objections to various obstacles within

these procedures for expeditious approval of alternate test procedures. Four analytical instrument manufacturers commented that by limiting of application for review and/or approval of alternate test procedures to NPDES permit holders, § 136.4 became an impediment to the commercial development of new or improved measurement devices based on new measurement principles. Applications for such review and/or approval will now be accepted from any person. The intent of the alternate test procedure is to allow the use of measurement systems which are known to be equivalent to the approved test procedures in waste water discharges.

Applications for approval of alternate test procedures applicable to specific discharges will continue to be made only by NPDES permit holders, and approval of such applications will be made on a case-by-case basis by the Regional Administrator in whose Region the discharge is made.

Applications for approval of alternate test procedures which are intended for nationwide use can now be submitted by any person directly to the Director of the Environmental Monitoring and Support Laboratory in Cincinnati. Such applications should include a complete methods write-up, any literature references, comparability data between the proposed alternate test procedure and those already approved by the Administrator. The application should include precision and accuracy data of the proposed alternate test procedure and data confirming the general applicability of the test procedure to the industrial categories of waste water for which it is intended. The Director of the Environmental Monitoring and Support Laboratory, after review of submitted information, will recommend approval or rejection of the application to the Administrator, or he will return the application to the applicant for more information. Approval or rejection of applications for test procedures intended for nationwide use will be made by the Administrator, after considering the recommendation made by the Director of the Environmental Monitoring and Support Laboratory, Cincinnati. Since the Agency considers these procedures for approval of alternate test procedures for nationwide use to be interim procedures, we will welcome suggestions for criteria for approval of alternate test procedures for nationwide use. Interested persons should submit their written comments in triplicate on or before June 1, 1977 to: Dr. Robert B. Medz, Environmental Protection Technologist, Monitoring Quality Assurance Standardization, Office of Monitoring and Technical Support (RD-680), Environmental Protection Agency, Washington, D.C. 20460.

(H) *Freedom of Information.* A copy of all public comments, an analysis by parameter of those comments, and documents providing further information on the rationale for the changes made in the final regulation are available for inspection and copying at the Environmental Protection Agency Public Information Reference Unit, Room 2922, Waterside Mall, 401 M Street, SW., Washington, D.C. 20460, during normal business hours. The EPA information regulation 40 CFR 2 provides that a reasonable fee may be charged for copying such documents.

Effective date: These amendments become effective on April 1, 1977.

Dated: November 19, 1976.

JOHN QUARLES,
Acting Administrator,
Environmental Protection Agency.

Chapter I, Subchapter D, of Title 40, Code of Federal Regulations is amended as follows:

1. In § 136.2, paragraphs (f), (g), and (h) are amended to read as follows:

§ 136.2 Definitions.

* * * * *

(f) "Standard Methods" means *Standard Methods for the Examination of Water and Waste Water*, 14th Edition, 1976. This publication is available from the American Public Health Association, 1015 18th Street, N.W., Washington, D.C. 20036.

(g) "ASTM" means *Annual Book of Standards, Part 31, Water, 1975.* This publication is available from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

(h) "EPA Methods" means *Methods for Chemical Analysis of Water and Waste, 1974.* Methods Development and Quality Assurance Research Laboratory, National Environmental Research Center, Cincinnati, Ohio 45268; U.S. Environmental Protection Agency, Office of Technology Transfer, Industrial Environmental Research Laboratory, Cincinnati, Ohio 45268. This publication is available from the Office of Technology Transfer.

2. In § 136.3, the second sentence of paragraph (b) is amended, and a new paragraph (c) is added to read as follows:

§ 136.3 Identification of test procedures.

* * * * *

(b) * * * Under such circumstances, additional test procedures for analysis of pollutants may be specified by the Regional Administrator or the Director upon the recommendation of the Director of the Environmental Monitoring and Support Laboratory, Cincinnati.

(c) Under certain circumstances, the Administrator may approve, upon recommendation by the Director, Environmental Monitoring and Support Laboratory, Cincinnati, additional alternate test procedures for nationwide use.

3. Table I of § 136.3 is revised by listing the parameters alphabetically; by adding 44 new parameters; by adding a fourth column under references listing equivalent United States Geological Survey methods; by adding a fifth column under references listing miscellaneous equivalent methods; by deleting footnotes 1 through 7 and adding 24 new footnotes, to read as follows:

* * * * *

TABLE I.—*List of approved test procedures*[1]

Parameter and units	Method	1974 EPA methods	14th ed. standard methods	References (page nos.) Pt. 31 1975 ASTM	References (page nos.) USGS methods[2]	Other approved methods
1. Acidity, as $CaCO_3$[3], milligrams per liter.	Electrometric end point (pH of 8.2) or phenolphthalein end point.	1	273(44)	116	40	[4](607)
2. Alkalinity, as $CaCO_3$[3], milligrams per liter.	Electrometric titration (only to pH 4.5) manual or automated, or equivalent automated methods.	3 5a	278	111	41	[4](607)
3. Ammonia (as N), milligrams per liter.	Manual distillation[5] (at pH 9.5) followed by nesslerization, titration, electrode, Automated phenolate.	159 165 168	410 412 416	237	116	[4](614)
BACTERIA						
4. Coliform (fecal)[6], number per 100 ml.	MPN;[6] membrane filter.		922 927		[7](45)	
5. Coliform (fecal)[6] in presence of chlorine, number per 100 ml.	do.[6]		922 928, 937			
6. Coliform (total),[6] number per 100 ml.	do.[6]		916 928		[7](38)	
7. Coliform (total)[6] in presence of chlorine, number per 100 ml.	MPN;[6] membrane filter with enrichment.		916 933			
8. Fecal streptococci,[6] number per 100 ml.	MPN;[6] membrane filter; plate count.		943 944 947		[7](50)	
9. Benzidine, milligrams per liter.	Oxidation—colorimetric[8]					
10. Biochemical oxygen demand, 5-d (BOD_5), milligrams per liter.	Winkler (Azide modification) or electrode method.		543		[9](50)	[10](17)
11. Bromide, milligrams per liter.	Titrimetric, iodine-iodate.	14		323	58	
12. Chemical oxygen demand (COD), milligrams per liter.	Dichromate reflux.	20	550	473	124	[4](610) [10](17)
13. Chloride, milligrams per liter.	Silver nitrate; mercuric nitrate; or automated colorimetric-ferricyanide.	29 31	308 304 313	267 265	[11](46)	[4](615)

See footnotes at end of table.

Parameter and units	Method	1974 EPA methods	14th ed. standard methods	References (page nos.) Pt. 31 1975 ASTM	References (page nos.) USGS methods [2]	Other approved methods
14. Chlorinated organic compounds (except pesticides), milligrams per liter.	Gas chromatography [13]					
15. Chlorine—total residual, milligrams per liter.	Iodometric titration, amperometric or starch-iodine end-point; DPD colorimetric or Titrimetric methods (these last 2 are interim methods pending laboratory testing).	35	318 322 322 329	278		
16. Color, platinum cobalt units or dominant wave length, hue, luminance, purity.	Colorimetric; spectrophotometric; or ADMI procedure.[13]	26 30	64 66		82	
17. Cyanide, total,[14] milligrams per liter.	Distillation followed by silver nitrate titration or pyridine pyrazolone (or barbituric acid) colorimetric.	40	361	505	85	[19](22)
18. Cyanide amenable to chlorination, milligrams per liter.	do	40	376	505		
19. Dissolved oxygen, milligrams per liter.	Winkler (Azide modification) or electrode method.	51 56	443 450	368	126	[3](600)
20. Fluoride, milligrams per liter.	Distillation [4] followed by ion electrode; SPADNS; or automated complexone.	65 59 61	389 391 393 414	307 305	93	
21. Hardness—Total, as $CaCO_3$, milligrams per liter.	EDTA titration; automated colorimetric; or atomic absorption (sum of Ca and Mg as their respective carbonates).	68 70	202	161	94	[3](617)
22. Hydrogen ion (pH), pH units.	Electrometric measurement.	239	460	178	129	[3](606)
23. Kjeldahl nitrogen (as N), milligrams per liter.	Digestion and distillation followed by nesslerization, titration, or electrode; automated digestion automated phenolate.	175 165 182	437		122	[3](612)
METALS						
24. Aluminum—Total, milligrams per liter.	Digestion [15] followed by atomic absorption [16] or by colorimetric (Eriochrome Cyanine R).	92	153 171		[11] (10)	
25. Aluminum—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced methods for total aluminum.					
26. Antimony—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[16]	94				
27. Antimony—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total antimony.					
28. Arsenic—Total, milligrams per liter.	Digestion followed by silver diethyldithiocarbamate; or atomic absorption.[15] [16]	9 98	286 293 189		[11] (31) [11] (37)	
29. Arsenic—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total arsenic.					
30. Barium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[16]	97	152		82	
31. Barium—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total barium.					
32. Beryllium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption [16] or by colorimetric (Aluminon).	99	152 177		83	
33. Beryllium—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total beryllium.					
34. Boron—Total, milligrams per liter.	Colorimetric (Curcumin)	13	287			
35. Boron—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total boron.					
36. Cadmium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption [16] or by colorimetric (Dithizone).	101	148 182	345	82 [3] (619) [18] (37)	
37. Cadmium—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total cadmium.					
38. Calcium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption; or EDTA titration.	103	148 159	345	88	
39. Calcium—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total calcium.					
40. Chromium VI, milligrams per liter.	Extraction and atomic absorption; colorimetric (Diphenylcarbazide).	89, 105	192		76 75	
41. Chromium VI—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for chromium VI.					
42. Chromium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption [16] or by colorimetric (Diphenylcarbazide).	105	148 192	345 288	78 77	[3] (619)
43. Chromium—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total chromium.					

See footnotes at end of table.

Parameter and units	Method	1974 EPA methods	14th ed. Standard methods	References (page nos.) Pt. 1 1975 ASTM	USGS methods [2]	Other approved methods
44. Cobalt—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[16]	107	148	345	80	[19] (37)
45. Cobalt—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total cobalt.					
46. Copper—Total, milligrams per liter.	Digestion [15] followed by atomic absorption [16] or by colorimetric (Neocuproine).	108	148 196	345 2-3	83 [3] (619)	[19] (37)
47. Copper—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total copper.					
48. Gold—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[16]					
49. Iridium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[16]					
50. Iron—Total, milligrams per liter.	Digestion [15] followed by atomic absorption [16] or by colorimetric (Phenanthroline).	110	148 208	345 326	102	[3] (619)
51. Iron—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total iron.					
52. Lead—Total, milligrams per liter.	Digestion [15] followed by atomic absorption [16] or by colorimetric (Ditilizone).	112	148 215	345	105	[3] (619)
53. Lead—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total lead.					
54. Magnesium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption; or gravimetric.	114	148 221	345	109	[3] (619)
55. Magnesium—Dissolved milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total magnesium.					
56. Manganese—Total milligrams per liter.	Digestion [15] followed by atomic absorption [16] or by colorimetric (Persulfate or periodate).	116	148 225, 227	345	151	[3] (619)
57. Manganese—Dissolved milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total manganese.					
58. Mercury—Total, milligrams per liter.	Flameless atomic absorption.	118	156	338	[11] (51)	
59. Mercury—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total mercury.					
60. Molybdenum—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[16]	130		350		
61. Molybdenum—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total molybdenum.					
62. Nickel—Total, milligrams per liter.	Digestion [15] followed by atomic absorption [16] or by colorimetric (Heptoxime).	141	148	345	115	
63. Nickel—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total nickel.					
64. Osmium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[16]					
65. Palladium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[16]					
66. Platinum—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[16]					
67. Potassium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption, colorimetric (Cobaltinitrite), or by flame photometric.	143	 235 284	 403	124	[3] (620)
68. Potassium—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total potassium.					
69. Rhodium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[16]					
70. Ruthenium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[16]					
71. Selenium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[16] [18]	145	159			
72. Selenium—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total selenium.					
73. Silica—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by colorimetric (Molybdosilicate).	274	467	308	130	
74. Silver—Total,[20] milligrams per liter.	Digestion [15] followed by atomic absorption [16] or by colorimetric (Dithizone).	146	148 243		142	[3] (619) [19] (37)
75. Silver—Dissolved,[20] milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total silver.					
76. Sodium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption or by flame photometric.	147	 250	 403	143	[3] (621)
77. Sodium—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total sodium.					

See footnotes at end of table.

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Parameter and units	Method	1974 EPA methods	14th ed. standard methods	References (page nos.) Pt. 31 1975 ASTM	References (page nos.) USGS methods [1]	Other approved methods
78. Thallium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[16]	149				
79. Thallium—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total thallium.					
80. Tin—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[16]	150			[11] (65)	
81. Tin—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total tin.					
82. Titanium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption.[16]	151				
83. Titanium—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total titanium.					
84. Vanadium—Total, milligrams per liter.	Digestion [15] followed by atomic absorption [16] or by colorimetric (Gallic acid).	153	152 260	441	[11] (67)	
85. Vanadium—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total vanadium.					
86. Zinc—Total, milligrams per liter.	Digestion [15] followed by atomic absorption [16] or by colorimetric (Dithizone).	155	148 265	345	159 [9](619) [10](37)	
87. Zinc—Dissolved, milligrams per liter.	0.45 micron filtration [17] followed by referenced method for total zinc.					
88. Nitrate as N, milligrams per liter.	Cadmium reduction; brucine sulfate; automated cadmium or hydrazine reduction.[23]	201 207 207	423 427 420	358	119 [9](614) [10](28)	
89. Nitrate as N, milligrams per liter.	Manual or automated colorimetric (Diazotization).	215	434		121	
90. Oil and grease, milligrams per liter.	Liquid-liquid extraction with trichloro-trifluoroethane-gravimetric.	229	515			
91. Organic carbon; total (TOC), milligrams per liter.	Combustion—Infrared method.[23]	236	532	467	[12] (4)	
92. Organic nitrogen (as N), milligrams per liter.	Kjeldahl nitrogen minus ammonia nitrogen.	175, 159	437		122 [9] (612, 614)	
93. Orthophosphate (as P), milligrams per liter.	Manual or automated ascorbic acid reduction.	249 256	461 624	384	131 [9] (621)	
94. Pentachlorophenol, milligrams per liter.	Gas chromatography [18]					
95. Pesticides, milligrams per liter.	do.[18]		555	529	[20] (24)	
96. Phenols, milligrams per liter.	Colorimetric, (4AAP)	241	582	545		
97. Phosphorus (elemental), milligrams per liter.	Gas chromatography [18]					
98. Phosphorus; total (as P), milligrams per liter.	Persulfate digestion followed by manual or automated ascorbic acid reduction.	249 256	476, 451 624	384	133 [9] (621)	
RADIOLOGICAL						
99. Alpha—Total, pCi per liter.	Proportional or scintillation counter.		648	591 [13](75+78)		
100. Alpha—Counting error, pCi per liter.	do.		648	594	[11] (79)	
101. Beta—Total, pCi per liter.	Proportional counter.		648	601 [13](75+78)		
102. Beta—Counting error, pCi per liter.	do.		648	606	[11] (79)	
103. (a) Radium—Total, pCi per liter.	do.		661	661		
(b) ^{226}Ra, pCi per liter.	Scintillation counter.		667		[11] (81)	
RESIDUE						
104. Total, milligrams per liter.	Gravimetric, 103 to 105° C.	270	91			
105. Total dissolved (filterable), milligrams per liter.	Glass fiber filtration, 180° C.	266	92			
106. Total suspended (nonfilterable), milligrams per liter.	Glass fiber filtration, 103 to 105° C.	266	94			
107. Settleable, milliliters per liter or milligrams per liter.	Volumetric or gravimetric.		95			
108. Total volatile, milligrams per liter.	Gravimetric, 550° C.	272	95			
109. Specific conductance, micromhos per centimeter at 25° C.	Wheatstone bridge conductimetry.	275	71	120	148	[9] (606)
110. Sulfate (as SO_4), milligrams per liter.	Gravimetric; turbidimetric; or automated colorimetric (barium chloranilate).	277 279	493 498	424 425		[9] (624) [9] (623)
111. Sulfide (as S), milligrams per liter.	Titrimetric—iodine for levels greater than 1 mg per liter; Methylene blue photometric.	284	505 503		154	
112. Sulfite (as SO_3), milligrams per liter.	Titrimetric, iodine-iodate	285	508	435		
113. Surfactants, milligrams per liter.	Colorimetric (Methylene blue).	157	600	490	[12] (11)	
114. Temperature, degrees C.	Calibrated glass or electrometric thermometer.	286	125		[21] (31)	
115. Turbidity, NTU.	Nephelometric.	266	132	223	156	

[1] Recommendations for sampling and preservation of samples according to parameter measured may be found in "Methods for Chemical Analysis of Water and Wastes, 1974" U.S. Environmental Protection Agency, table 2, pp. viii-xi.

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[1] All page references for USGS methods, unless otherwise noted, are to Brown, E., Skougstad, M. W., and Fishman, M. J., "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases," U.S. Geological Survey Techniques of Water-Resources Inv., book 5, ch. A1, (1970).

[2] EPA comparable method may be found on indicated page of "Official Methods of Analysis of the Association of Official Analytical Chemists" methods manual, 12th ed. (1975).

[4] Manual distillation is not required if comparability data on representative effluent samples are on company file to show that this preliminary distillation step is not necessary; however, manual distillation will be required to resolve any controversies.

[5] The method used must be specified.

[6] The 5 tube MPN is used.

[7] Slack, K. V. and others, "Methods for Collection and Analysis of Aquatic Biological and Microbiological Samples: U.S. Geological Survey Techniques of Water-Resources Inv. book 5, ch. A4 (1973)."

[8] Since the membrane filter technique usually yields low and variable recovery from chlorinated wastewaters, the MPN method will be required to resolve any controversies.

[9] Adequately tested methods for benzidine are not available. Until approved methods are available, the following interim method can be used for the estimation of benzidine: (1) "Method for Benzidine and Its Salts in Wastewaters," available from Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268.

[10] American National Standard on Photographic Processing Effluents, Apr. 2, 1975. Available from ANSI, 1430 Broadway, New York, N.Y. 10018.

[11] Fishman, M. J. and Brown, Eugene, "Selected Methods of the U.S. Geological Survey for Analysis of Wastewaters," (1976) open-file report 76-177.

[12] Procedures for pentachlorophenol, chlorinated organic compounds and pesticides can be obtained from the Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268.

[13] Color method (ADMI procedure) available from Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268.

[14] For samples suspected of having thiocyanate interference, magnesium chloride is used as the digestion catalyst. In the approved test procedure for cyanides, the recommended catalysts are replaced with 20 ml of a solution of 510 g/l magnesium chloride ($MgCl_2 \cdot 6H_2O$). This substitution will eliminate thiocyanate interference for both total cyanide and cyanide amenable to chlorination measurements.

[15] For the determination of total metals the sample is not filtered before processing. Because vigorous digestion procedures may result in a loss of certain metals through precipitation, a less vigorous treatment is recommended as given on p. 83 (4.1.4) of "Methods for Chemical Analysis of Water and Wastes" (1974). In those instances where a more vigorous digestion is desired the procedure on p. 82 (4.1.3) should be followed. For the measurement of the noble metal series (gold, iridium, osmium, palladium, platinum, rhodium and ruthenium), an aqua regia digestion is to be substituted as follows: Transfer a representitive aliquot of the well-mixed sample to a Griffin beaker and add 3 ml of concentrated redistilled HNO_3. Place the beaker on a steam bath and evaporate to dryness. Cool the beaker and cautiously add a 5 ml portion of aqua regia. (Aqua regia is prepared immediately before use by carefully adding 3 volumes of concentrated HCl to one volume of concentrated HNO_3.) Cover the beaker with a watch glass and return to the steam bath. Continue heating the covered beaker for 50 min. Remove cover and evaporate to dryness. Cool and take up the residue in a small quantity of 1:1 HCl. Wash down the beaker walls and watch glass with distilled water and filter the sample to remove silicates and other insoluble material that could clog the atomizer. Adjust the volume to some predetermined value based on the expected metal concentration. The sample is now ready for analysis.

[16] As the various furnace devices (flameless AA) are essentially atomic absorption techniques, they are considered to be approved test methods. Methods of standard addition are to be followed as noted in p. 78 of "Methods for Chemical Analysis of Water and Wastes," 1974.

[17] Dissolved metals are defined as those constituents which will pass though a 0.45 μm membrane filter. A prefiltration is permissible to free the sample from larger suspended solids. Filter the sample as soon as practical after collection using the first 50 to 100 ml to rinse the filter flask. (Glass or plastic filtering apparatus are recommended to avoid possible contamination.) Discard the portion used to rinse the flask and collect the required volume of filtrate. Acidify the filtrate with 1:1 redistilled HNO_3 to a pH of 2. Normally, 3 ml of (1:1) acid per liter should be sufficient to preserve the samples.

[18] See "Atomic Absorption Newsletter," vol. 13, 75 (1974). Available from Perkin-Elmer Corp., Main Ave., Norwalk, Conn. 06852.

[19] Method available from Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268.

[20] Recommended methods for the analysis of silver in industrial wastewaters at concentrations of 1 mg/l and above are inadequate where silver exists as an inorganic halide. Silver halides such as the bromide and chloride are relatively insoluble in reagents such as nitric acid but are readily soluble in an aqueous buffer of sodium thiosulfate and sodium hydroxide to a pH of 12. Therefore, for levels of silver above 1 mg/l 20 ml of sample should be diluted to 100 ml by adding 40 ml each of 2M $Na_2S_2O_3$ and 2M NaOH. Standards should be prepared in the same manner. For levels of silver below 1 mg/l the recommended method is satisfactory.

[21] An automated hydrazine reduction method is available from the Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268.

[22] A number of such systems manufactured by various companies are considered to be comparable in their performance. In addition, another technique, based on combustion-methane detection is also acceptable.

[23] Goerlitz, D., Brown, E., "Methods for Analysis of Organic Substances in Water": U.S. Geological Survey Techniques of Water-Resources Inv., book 5, ch. A3 (1972).

[24] R. F. Addison and R. G. Ackman, "Direct Determination of Elemental Phosphorus by Gas-Liquid Chromatography," "Journal of Chromatography," vol. 47, No. 3, pp. 421-426, 1970.

[25] The method found on p. 75 measures only the dissolved portion while the method on p. 78 measures only suspended. Therefore, the 2 results must be added together to obtain "total."

[26] Stevens, H. H., Ficke, J. F., and Smoot, G. F., "Water Temperature—Influential Factors, Field Measurement and Data Presentation: U.S. Geological Survey Techniques of Water Resources Inv., book 1 (1975)."

4. In § 136.4, the second sentence of paragraph (c) is amended by deleting the word "subchapter" immediately following the phrase "procedure under this" and immediately preceding the word "shall" and replaced with the phrase "paragraph c;" and § 136.4 is amended by adding a new paragraph (d) to read as follows:

§ 136.4 Application for alternate test procedures.

* * * * * * *

(c) * * * Any application for an alternate test procedure under this paragraph (c) shall: * * *

(d) An application for approval of an alternate test procedure for nationwide use may be made by letter in triplicate to the Director, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268. Any application for an alternate test procedure under this paragraph (d) shall:

(1) Provide the name and address of the responsible person or firm making the application.

(2) Identify the pollutant(s) or parameter(s) for which nationwide approval of an alternate testing procedure is being requested.

(3) Provide a detailed description of the proposed alternate procedure, together with references to published or other studies confirming the general applicability of the alternate test procedure to the pollutant(s) or parameter(s) in waste water discharges from representative and specified industrial or other categories.

(4) Provide comparability data for the performance of the proposed alternate test procedure compared to the performance of the approved test procedures.

§ 136.5 [Amended]

5. In § 136.5, paragraph (a) is amended by inserting the phrase "proposed by the responsible person or firm making the discharge" immediately after the words "test procedure" and before the period that ends the paragraph.

6. In § 136.5, paragraph (b) is amended by inserting in the first sentence the phrase "proposed by the responsible person or firm making the discharge" immediately after the words "such application" and immediately before the comma. The second sentence of paragraph (b) is amended by deleting the phrase "Methods Development and Quality Assurance Research Laboratory" immediately after the phrase "State Permit Program and to the Director of the" at the end of the sentence, and inserting in its place the phrase "Environmental Monitoring and Support Laboratory, Cincinnati."

7. In § 136.5, paragraph (c) is amended by inserting the phrase "proposed by the responsible person or firm making the discharge" immediately after the phrase "application for an alternate test procedure" and immediately before the comma; and by deleting the phrase "Methods Development and Quality Assurance Laboratory" immediately after the phrase "application to the Director of the" and immediately before the phrase "for review and recommendation" and inserting in its place the phrase "Environmental Monitoring and Support Laboratory, Cincinnati."

8. In § 136.5, the first sentence of paragraph (d) is amended by inserting the phrase, "proposed by the responsible person or firm making the discharge," immediately after the phrase, "application for an alternate test procedure," and immediately before the comma.

The second sentence of paragraph (d) is amended by deleting the phrase, "Methods Development and Quality Assurance Research Laboratory," immediately after the phrase, "to the Regional Administrator by the Director of the," and immediately preceding the period ending the sentence and inserting in its place the phrase, "Environmental Monitoring and Support Laboratory, Cincinnati."

The third sentence of paragraph (d) is amended by deleting the phrase, "Methods Development and Quality Assurance Research Laboratory," immediately after the phrase, "forwarded to the Director," and immediately before the second comma and by inserting in its place the phrase, "Environmental Monitoring and Support Laboratory, Cincinnati."

9. Section 136.5 is amended by the addition of a new paragraph (e) to read as follows:

§ 136.5 Approval of alternate test procedures.

* * * * *

(g) Within ninety days of the receipt by the Director of the Environmental Monitoring and Support Laboratory, Cincinnati of an application for an alternate test procedure for nationwide use, the Director of the Environmental Monitoring and Support Laboratory, Cincinnati shall notify the applicant of his recommendation to the Administrator to approve or reject the application, or shall specify additional information which is required to determine whether to approve the proposed test procedure. After such notification, an alternate method determined by the Administrator to satisfy the applicable requirements of this part shall be approved for nationwide use to satisfy the requirements of this subchapter; alternate test procedures determined by the Administrator not to meet the applicable requirements of this part shall be rejected. Notice of these determinations shall be submitted for publication in the FEDERAL REGISTER not later than 15 days after such notification and determination is made.

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Title 40—Protection of Environment

CHAPTER I—ENVIRONMENTAL PROTECTION AGENCY

SUBCHAPTER D—WATER PROGRAMS

PART 136—GUIDELINES ESTABLISHING TEST PROCEDURES FOR THE ANALYSIS OF POLLUTANTS

Amendment of Regulations; Corrections

In FR Doc. 76-35032 appearing at pages 52780 to 52786 in the FEDERAL REGISTER of Wednesday, December 1, 1976, the following changes should be made:

§ 135.3 [Amended]

1. On Page 52783, for parameter number 62, Nickel—Total, add "232" to the page references in the column under the 14th edition of Standard Methods opposite the colorimetric method designation.

2. On page 52784, for parameter number 89, change the parameter designation from "Nitrate" to "Nitrite."

3. On page 52784, for parameter number 96, Phenols, delete the present method designation, "Colorimetric, (4AAP)," and replace it with the method designation, "Distillation followed by colorimetric, (4AAP)"; delete the page reference in the column under the 14th edition of Standard Methods, "582," and replace it with page number "574".

Dated: January 10, 1977.

WILSON K. TALLEY,
Assistant Administrator for Research and Development.

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